

***A MODEL FOR REDUCING ENERGY CONSUMPTION IN EXISTING  
OFFICE BUILDINGS: A CASE FOR NIGERIA AND UNITED KINGDOM  
BUILDING OWNERS & FACILITIES MANAGERS***



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## Dedication

This work is dedicated to Almighty God, the creator of heaven and earth; and His Son, Our Lord Jesus Christ in whom everything exists in equilibrium.

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## Declaration

I confirm that this work and materials used herein from other sources have been properly acknowledged. The substance of this thesis is my original work and has not been submitted in any form for another degree or diploma.



## Abstract

The study investigated critical factors that affect office building energy performance in Nigeria compared to the UK; and developed an assessment and benchmarking framework for identifying appropriate operational, technical and behavioural solutions to improve energy performance of existing buildings.

The mixed methods, multiple-case study approach was adopted for collecting energy used data from selected ten existing office buildings in both countries. A literature review was used to establish worldwide view on factors influencing building energy performance. The selected factors were transformed into theoretical framework variables. These variables were further translated into an operational sustainability as an audit tool for establishing initial cases' energy performance assessment.

Operational energy data from case buildings were collected via: electricity bills, meter readings and fuels' receipts/ invoices. Also, three online questionnaire surveys: a post occupancy evaluation for the assessment of comfort and energy performance of the ten buildings; a survey of facilities managers' perception of managerial, operational and technical issues; and a model validation survey for confirmation of established factors from earlier two surveys, was employed. Likewise, a one-on-one semi-structured interview was utilised for owners/ managing directors and facilities managers of case buildings. Whilst, Structural equation modelling, analysis based on the validation survey, was employed to examine the dependencies and interdependencies of the critical factors. The IBM, SPSS 22 and AMOS 23 were used for the exploratory factor analysis and confirmatory factor analysis based on maximum likelihood estimations; which produced validated measurement and structural models.

The study identified 52 critical factors that were transformed into 17 most critical factors impacting building energy performance in Nigeria and UK. The model identified new indicators for building energy performance; and established causality between building energy performance, management policy, operations and strategic driver as standard metrics for building energy efficiency assessment and benchmark. Likewise, it established a strong network of strategic drivers underpinned by strategic sustainability policy/ facilities management as mediator. The Nigeria buildings' performance was found to depend largely on the context in which they operate in apart from the weather. Whereas, validity of climate variability as a critical factor of the UK case buildings' energy performance was established.

Institutionalised regulatory framework is suggested for Nigeria and sub-Saharan Africa countries as a control measure. The building energy performance model and its operational sustainability tool could be used as energy assessment and benchmark. It serves as a dashboard that encapsulates the energy efficiency performance and the absolute impacts of intervening factors. Finally, it presents insight into a critical path for intervention schemes as implemented; and the use of the strategic sustainability policy/ facilities management as mediation for improving building energy performance.

*Key Words:* Building Energy performance, Climate Change, Carbon Emissions, Energy Efficiency, Facilities Management, Nigeria, Sustainability, Structural Equation Modelling, Strategic Energy management, UK.

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## Abbreviations

BAM: Built Asset Management  
BAS: Building Automation Systems  
BCO<sub>2</sub>: Building Carbon Emissions  
BCO<sub>2</sub>I: Building Carbon Emissions Intensity  
BCT: Behaviour Change Tool  
BEC: Building Energy Cost  
BECI: Building Energy Cost Intensity  
BECS: Building Energy Codes and Standards  
BEU: Building Energy Use  
BEUI: Building Energy Use Intensity  
BEE: Building Energy Efficiency  
BEM: Building Energy Management  
BEMTechs: Building Energy Management Technologies  
BEP: Building Energy Performance  
BIM: Building Information Modelling  
CCH: Climate Change  
CDD: Cooling Degree Day  
COPs: Conference of Parties  
CHP: Combined Heat and Power  
DAS: Data Acquisition System  
DECs: Display Energy Certificates  
DECC: Department of Energy and Climate Change  
ECB: Energy Consumption Behaviour  
ECS: Energy Codes and Standards  
EE: Energy Efficiency  
EEP: Energy Efficiency Performance  
EMS: Environmental Management System  
EPBD: Energy Performance of Buildings Directive  
EPCs: Energy Performance Certificates  
EPL: Energy Performer Line  
EPLs: Energy Performance Indices  
FM: Facilities Management  
FMs: Facilities Managers  
HDD: Heating Degree Day  
HVAC: Heating Ventilation & Air Conditioning  
KPIs: Key Performance Indicators  
LZC: Low-Zero Carbon  
NPI: Normalised Performance Index  
OLS: Ordinary Least Squares  
OS: Operational Sustainability  
OST: Operational Sustainability Tool  
PBC: Perceived Behavioural Control  
POE: Post Occupancy Evaluation  
PV: Photo Voltaic  
REN: Renewable energy  
RETOs: Renewable Energy Technologies  
RIA: Relative Index Analysis  
SBM: Sustainable Management of Building  
SD: Sustainable Development  
SEQM: Structural Equation Modelling  
SEM: Strategic Energy Management  
SFM: Strategic Facilities Management  
SP: Sustainable Policy  
SSP: Strategic Sustainable Policy  
UNFCCC: United Nations Framework Conference on Climate Change



# 1 Chapter One: Introduction

## 1.1 STATEMENT OF THE PROBLEMS

In the UK and other developed countries, integrated approaches such as established regulatory frameworks (building energy codes, policies, institutional control and enforcement), have been successful in stabilising their GHG emissions (Dascalaki et al., 2012; Haapio and Viitaniemi, 2008). Also, other factors such as: continuing research on the building energy performance (BEP) and efficiency; planning for carbon reduction initiatives; and provisions of enabling environment (policies, monitoring and controls, and tools), are successful approaches adopted in the UK by government.

The same cannot be said of sub-Saharan African (SSA) countries, as traditional approaches used in the region have been unsuccessful compared to developed countries. Although, most SSA countries have building regulations, in most instances, these codes lack fuel efficiency and carbon reduction regulations. Likewise, the lack of: government's will and institutional capacities; skills and technical know-how; robust building energy use (BEU) data; technology; and non-existence of energy codes or building energy codes in these countries are barriers to BEP.

In Nigeria, the building industry lack specific energy parameters for assessing energy use and benchmarking buildings' performance. This is due to a lack of research studies, standardised metrics and performance indicators on BEU. Consequently, the energy efficiency (EE) of buildings is affected by both poor design decisions and management practices.

The UK's Code for Sustainable Homes and Building Research Establishment environmental assessment method (BREEAM) etc., are exemplar voluntary programmes that influence both design process, construction and operation of buildings. These schemes specify performance standards with metrics and indicators for the assessment and benchmarking of buildings that complement national building codes. These successful schemes used by government and organisations in the UK could be potentially adapted to the Nigerian context. However, the UK's government former Code for Sustainable Homes established in 2007, was withdrawn in 27<sup>th</sup> March 2015 (DCLG, 2015).

The Nigeria's facilities management (FM) industry is in its infancy phase compared to the maturity of the UK's FM industry. Whereas, in the UK, operational FM underpinned with sustainable policy (SP) is fully developed. The UK's Built Asset portfolio is a major subsector of her construction industry. However, in Nigeria, facility owners and organisations lack the will to incorporate SP and strategic facilities management (SFM) into the built asset management (BAM) portfolio. Most commercial buildings are operated by non-professionals who lack the required FM skills and know-how.

Another inherent problem is increasing energy demand and poor economic performance associated with the population explosion in SSA. Data from the International Energy Agency (IEA) reported that Africa's total energy demand increased from 499Mtoe (2000) to 630Mtoe (2007), and is projected to be 716Mtoe in 2015, and 873Mtoe in 2030, which represent an average annual increment of 1.4% (IEA, 2009). For instance, World Bank report (World Bank, 2013), cited Nigeria's population at 173.6million and poverty head count ratio of 46.0% (2010). Also, estimated her poverty gap at 1.25 USD a day (PPP %), and CO<sub>2</sub> emission rate of 0.5Mtons per Capital is recorded. While SSA countries have average poverty head count ratio of 47.50%.

Economic performance, population and energy demand are established energy efficiency performance (EEP) indicators of countries. SSA accounts for 13% of the world's population, and 4% of global energy demand. Her energy demand grew by about 45% from 2000-2012, coupled with rapid population growth. Nigeria and South Africa both account for more than 45% of SSA total energy demand (IEA, 2014b). These indicators display poorer EEP of the building stock now and in future if not regulated. The data depict a poor EEP that affects the building stocks in SSA countries especially Nigeria.

The exemplary case of the UK's design legislations, operational codes and policies, could be adapted for Nigeria. Design legislation can improve the performance of new buildings, and affect the EE of existing buildings, which constitute the clear majority of the built environment and will do so for many years to come.

Energy conservation culture such as switch-off, is also not a common practice in Nigeria. Affluence is associated with constant use of lighting and air conditioning systems in buildings. This habit depicts attitudinal problem due to socioeconomic orientation and value systems,



which hinder BEP. Additionally, poor awareness of CO<sub>2</sub> emissions from buildings, coupled with low awareness on climate change (CCH) and GHGs are major problems hindering BEP in SSA.

Most buildings are now designed to use generators as an alternative source of electricity supply, because of irregular power generation and supply in Nigeria (IEA, 2014b). It is an acceptable norm to use generators in buildings in the region. This practice has become prevalent, as generators are used to power buildings' lighting and occupants' comfort. It is a source of GHGs emissions and noise pollution, and imposes heavy energy demands on buildings (Oyedepo, 2012).

Some past studies (Iwaro and Mwashia, 2010; Victor et al, 2014), have identified: lack of EE regulations and cost efficiency measures; and lack of awareness and skills in building energy control technologies as barriers to BEP. Likewise, awareness of energy control technologies and skills required for their operation and maintenance is very low in the region.

Lack of a robust and rigorous framework for BAM is also a barrier to improving BEP. A new way of managing existing buildings (on a day-day operations and planned refurbishments basis), is needed for improving BEP in SSA. Hence, developing a new building management model to improve BEP, informed the basis of this thesis.

## 1.2 APPROPRIATENESS OF THE RESEARCH

Increasingly, facilities managers are being tasked with the responsibility of changing the way buildings are managed to reduce energy use, whilst improving building performance. In the UK, FM's have developed a good understanding of the factors that affect the energy performance of existing buildings; and new metrics have been developed to measure the effect that management and refurbishment interventions have on building energy efficiency (BEE).

The UK's FM practice has been transformed from tactical to strategic base operations. New methods are being developed to exploit relationships between EE, and wider building performance including an added value agenda as part of sustainable FM strategies. Sustainable policies are now being developed to embed EE policies into the organisational culture. Hence,

in the UK and other developed countries, there is the beginning of the coherent approach to systematically improve the energy performance of existing buildings over their life cycle; via effective management policies.

The same cannot be said of Nigeria, as the lack of a framework model is the key issue. Thus, the development of an appropriate BEP framework underpinned by embedded strategic facilities policy (SSP)/ SFM and other critical factors that affects BEP is timely.

The need to also guard against the consequences of rapid climate change (CCH) and energy security has drawn increased attention to EE policy (Ryan et al., 2011). Most countries in the SSA region lack strategic policy measures against CCH impacts of buildings, hence, the need for research into BEP. Thus, the use of SSP, SFM and sustainable building management (SBM) model in managing BEP is timely. The outcomes of the research can be used as a baseline data to inform policy change in sub-Saharan Africa countries.

There is a dearth of building energy efficiency (BEE) and carbon emission research, studies, data, and information in the sub-Saharan African region. Most countries in the region lack EEP metrics and indicators for benchmarks in national building codes. The first building energy code in the region was published in South Africa in 2011, while the first known research on building energy efficiency tagged “a boost for energy efficient buildings in East Africa” was commissioned in May 2011 by the United Nations Habitat organisation. The UN-Habitat research was in collaboration with UNEP, the Global Environmental Facility (\$2,853,000 USD funding), and the governments of five East African countries of Kenya, Uganda, Tanzania, Rwanda and Burundi (UN-HABITAT, 2011).

Finally, this justifies the appropriate timing of this study, it is now apparent that sub-Saharan African countries need to embrace BEP to cut down on GHG emissions, secure national energy supply, and alleviate citizen’s energy poverty.

### 1.3 CONTRIBUTIONS TO KNOWLEDGE

Several works (Lovisa, 2014; Ifigenia, 2013; Lewis, 2012 etc.), have been undertaken on BEU, EE, sustainability and building, FM and building, etc., but none examines critical factors that affect BEU and BEP in Nigeria and the UK. Likewise, the relationships and independence of these elements; and impacts of embedded SP and SFM on BEP, have not been investigated.

Previous studies on: the impacts of climate change on BEP (Ifigenia, 2013); and use of building sustainability as an incentive for management of buildings (Lovisa, 2014), did not address current issues. Other studies: the use of FM's role and tools to drive building energy performance of buildings (Lewis, 2012); and study on the measurement, analysis, and prediction energy performance of buildings (Barley et al., 2005), did not examine current issues.

Other authors, who investigated barriers and drivers for sustainability and facilities management (Elmualim et al., 2010a; Ikediashi, Ogunlana and Ujene, 2014) failed to examine these specific issues. While studies on: actual energy use and their drivers in high performance buildings using the influences of technologies, behaviour, operation and maintenance (Li, Hong and Yan, 2014b); and energy retrofit options for reducing GHG emissions (Ibn-Mohammend, 2014), also did not consider the current issues.

Some past studies (Levine et al., 2007; GEF-UNDP, 2011; UN-HABITAT, 2011), have identified gaps in achieving BEP for the SSA region. They affirm that where energy data on buildings are available in developing countries, they are poorly collected and reported, making policy analysis and recommendation insufficiently robust. Also, there was a consensus that, research on BEP in the region would help: inform policy changes in national building codes; mainstream EE measures into building policies and regulations in reducing energy consumptions; and cutting down GHG emissions (Ibid).

The current study, however, specifically addresses the gaps in knowledge and could inform policy guidance; and inform baseline data availability on BEU and BEP contextual factors peculiar to the region. It could inform an acceptable assessment and benchmark framework based on robust and rigor for Nigeria and the SSA region.

The current research linked assessment and benchmark with SP, strategic management process, and SFM operation process, which made it possible to measure their relationships and establish links between factors. This is a unique method for Africa, as past studies, have demonstrated the need to link benchmarking studies to the strategic planning process, which should focus on understanding methods and operations rather than metrics.

The study carried out an in-depth literature review on BEU and CO<sub>2</sub> emissions in the SSA region. This has helped to fill the identified gaps in the literature; by exploring bottom-up assessments of GHG reduction opportunities and associated costs in buildings to develop a harmonized methodology for analysis as suggested by Levine et al., (2007).

## 1.4 SIGNIFICANCE OF THE STUDY

Earlier studies have identified fragmentation in the Nigerian built environment, which is poorly documented and not guided or monitored by sustainability tools or energy reduction intervention frameworks. Likewise, the lack of will by owners to incorporate sustainability policy and SFM in the Built Asset Management (BAM), are perceived to be barriers to improving BEP in Nigeria.

Though there are studies on the benefit of the use either tool (SP or SFM) on non-residential buildings. In Nigeria, there are no studies on the perceived and absolute benefits of the use of both (embedded SSP and SFM) together. Some studies identified an increasing trend in the use of fossil fuel-based generators to power buildings in Nigeria. However, there is no current work on the absolute impact of generator use in commercial buildings. Also, research on the critical factors serving as barriers and drivers for commercial BEP is lacking in Nigeria.

## 1.5 RESEARCH AIM AND OBJECTIVES

### 1.5.1 Aim

The aim of this study is:

- I. Develop an Assessment and Benchmarking Framework that will enable owners and facilities managers to identify appropriate operational, technical and behavioural solutions to improve the EE in existing buildings in Nigeria and UK.

### 1.5.2 Objectives

The research objectives are as follows:

- I. Identify the independent factors (strategic, operational, technical and behavioural) that affects existing BEP in Nigeria and the UK
- II. Identify the relationships and interdependencies between the independent factors; and the use of SSP/ SFM for improving BEP in both countries
- III. Identify the drivers and barriers that influence the effectiveness of the independent factors to affect existing BEP
- IV. Build up a theoretical framework model that relates the independent factors to the EE of existing buildings
- V. Develop a series of performance metrics (PMs) and key performance indicators (KPIs) to measure the effect of the independent factors on the existing BEP; and
- VI. Identify practical guidance on the application of the framework model to the Nigeria buildings.

### 1.6 RESEARCH QUESTIONS

This research seeks to answer the following questions:

- I. What are the critical factors influencing BEP in Nigeria and the UK?
- II. What are the relationships and interdependencies between these independent factors and the existing BEP in both countries?
- III. What are the peculiar drivers and barriers that affect BEP of existing buildings?
- IV. How could PMs and KPIs identify and develop as a range of energy performance metrics and KPIs; and be integrated into new model based on multiple-case study method?
- V. In what way, can SP and FM drive the low carbon goal in existing buildings?
- VI. How will the study's theoretical framework be translated into an integrated application for EE planning and operational based BEP management model?

## 1.7 RESEARCH METHODOLOGY

The core of scientific reasoning and knowledge is based on deductive and inductive reasoning. Hence, the current study derived its philosophical view from the concepts of deduct and induct paradigm. The combination of objectivism (positivism) and subjectivism (constructivism) based on concurrent triangulation will provide more robust and rigorous research findings (Bowling, 2009). Besides, adoption of deductive and inductive methods as the research philosophy is useful in establishing an acceptable framework for Nigeria and most sub-Sahara African countries. In this instance, both are most desirable and are employed in carrying out longitudinal energy use data measurement of case buildings; online questionnaire surveys and one-on-one interviews in gathering, developing and confirming relevant theories and hypothesis testing via cross validation of information sets.

### 1.7.1 Research Designs and Methods

The mixed methods of inquiry were adopted for this study based on an explanatory sequential design (Creswell, 2015). Case study approach was used for collecting energy use data from selected office buildings. While online questionnaire surveys and in-depth one-on-one interviews were deployed to seek stakeholders' opinion on sustainable management of BEP, and specific factors influencing official BEP in Nigeria.

Technical surveys of ten existing buildings (five buildings in Lagos, Nigeria and five buildings in Chelmsford, United Kingdom) were used to establish case building energy performance. While, two online questionnaire surveys were used to carry out post occupancy evaluation (POE) and model validation study through occupants' assessment of comfort and BEP assessment of the ten buildings. Likewise, the third online survey questionnaire was used to establish FMs' perception on SSP, SFM, technical and managerial solutions; metrics; and indexes. Whilst, a measurement and structural model based on SEQM was used to validate the study's theoretical framework via IBM, SPSS 22, AMOS 23.

## 1.8 SCOPE AND LIMITATIONS OF THE STUDY

The current study conducted EEP assessment of existing commercial buildings in Nigeria and benchmarked recorded data against other UK buildings. It also examined critical factors that impact on BEP; and the impact of combined SSP and SFM as strategic drivers on these buildings. The study engaged the use of quantitative and qualitative research techniques.

The goals amongst are to: evaluate total BEU, understand energy used sources, and identify adaptive energy performance metrics and KPIs for reducing, maintaining, and improving BEP of existing buildings in Nigeria. Different buildings have different consumption pattern and in restricting this variation, this research concentrates on non-domestic (commercial) buildings. The scope of this study is restricted to office or commercial buildings, and for the purpose of this research, ten office buildings were chosen for the explanatory study due to limited resources and time constraint in carrying out similar experiment on more commercial or office buildings.

The study includes an extensive literature review and theoretical framework developed from secondary data on concepts and theories of climate change, energy poverty, energy security, sustainable development, energy efficiency, facilities management, and zero carbon solutions. In addition, energy assessment and benchmarking in the UK and other developed countries' EE standards, EE policies, measures and building regulations were reviewed.

In achieving rigour and robustness, the consideration of critical literature review of SP and FM responsibilities as drivers for reducing BEU and improved BEP were investigated. Their contributions to the BAM portfolio and carbon footprint reduction for existing building stocks were undertaken.

## 1.9 THESIS ORGANISATION

The thesis is organised into ten chapters in relation to study aim, objectives and research questions as outlined briefly. Chapter one introduces the reader to the context of the research and the challenges addressed. Chapter two presents a critical review of extant literatures on global energy demand and CCH, sustainability issues and BEU, barriers and drivers to BEP,

interventions in BEP improvement and the business case for BEP. Whilst, chapter three explains the study's theoretical framework and its postulated applications.

Chapter four describes the overview of the philosophical research approaches, the strategy and tactics deployed. Chapter five illustrates the research plan, data collection and analytical techniques used and other steps that established the research. Chapter six describes the ten case buildings in detailed. Besides, it explains the actual assessment and benchmark process of the case BEP including techniques of NPI (Normalised Performance Index) and EPL (Energy Performance Line) used for them.

Chapter seven uses both quantitative and qualitative techniques to explore critical factors that affect BEP from users, professionals and owners' perspectives. Chapter eight explains the use of SEQM in modelling the identified critical factors in the BEP Model. Chapter nine presents the findings and discussion on case study used to demonstrate the study approach via triangulation and pattern matching. Finally, chapter ten summarised the conclusions drawn, presented implication of the findings and suggestions for future research.

## 1.10 SUMMARY

This chapter presents the background to the research study. It further explicates on these problems and their identifiable causes, and suggests possible solutions. The aim, objectives and research questions used in achieving them were elucidated. It further explained the research method deployed in meeting the study aims and objectives, and its contributions to knowledge. The next chapter reviews existing knowledge pertinent to the research topic.



## 2 Chapter Two: Review of Literature and Theory

### 2.1 INTRODUCTION

Global efforts against climate change (CCH) through improved BEP, has yielded more success in the developed countries compared to developing countries. Although several factors that account for this disparity are well established in extant literatures, it is how these factors interact with one another that is explored in this study. Also, a review of energy savings in existing building stocks via FM interventions is expedient and relevant in this context.

The chapter presents a global view of prior knowledge on CCH, BEU and BEP assessment and benchmarking. A critical examination of existing body of literatures on sustainability and BEP, is also undertaken. While, the concept of sustainable building management (SBM) in relation to SP and FM, as well as strategic energy management (SEM) for existing building stocks are explored. Also, business cases for reducing BEU and reducing CO<sub>2</sub> is undertaken. The findings from the review were used to inform the contextual framework model for the study.

### 2.2 CONTEXT TO THE STUDY

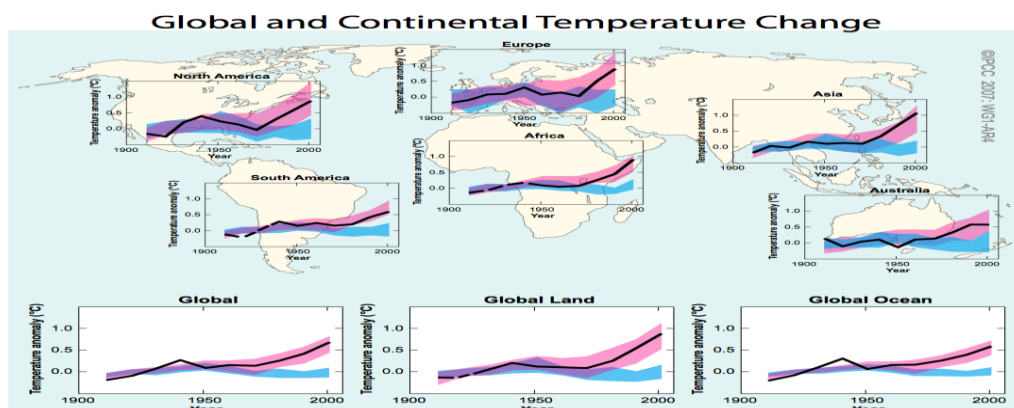
Several studies (IPCC, 2007; IEA, 2008), recognise CCH as the variability in global weather patterns. It is ascribed to be the fluctuation in the climate's statistical mean and variability of its properties over persistent period of decade(s) (Victor et al., 2014) with severe consequences. These consequences (extreme weather, flooding, urban heat waves, etc.), are a major threat to the steady growth of global economies (Stern, 2008; Nikolaou, Evangelinos and Leal Filho, 2015). Also, CCH exposes people, societies, economies, and the ecosystem to risks of uncertain occurrences that could be in the form of hazard vulnerability and exposure (Mastrandrea et al., 2014).

Globally, CCH is linked to consumption of fossil fuel and other GHGs emission sources (Escriva-Escriva, 2011). 80% of the world primary energy demand (WPED), is sourced from burning of fossil fuels, resulting in CO<sub>2</sub> and other GHGs emissions (Ibn-Mohammend, 2014). Available data trend reveals that the WPED is still increasing; and its use has been identified as the main cause of global warming and consequently CCH (IPCC, 2007; IEA, 2009).

Evidence from IPCC's studies (Levine et al., 2007; Victor et al., 2014), display corresponding incremental emissions of CO<sub>2</sub> and associated GHGs as WPED increases; and linked building energy consumption as one of its main sources. Between 1970 and 2010, human induced global GHGs emission increased from 28.7 to 49.0 GTCO<sub>2</sub>-eq/yr. Anthropogenic CO<sub>2</sub> emissions accounted for 78.0% of total GHGs emission for the same period (IPCC AR 4th & 5th). On the other hand, buildings are associated with the greatest percentage (56.6%) of global CO<sub>2</sub> emissions (1970-2010) (Ibid).

Past research by the IPCC (Levine et al., 2007) indicates the earth's surface temperature increased from 0.0°C in 1950 to 0.7°C in 2000 (Figure 2.1). In its study of Earth's surface temperature between 1900 and 2005, the IPCC used climate models to simulate natural and anthropogenic forcing, and is proven that the incident of global temperature rise with continental and global temperature changes is a reality. The panel revealed comparison of observed continental and global-scale changes in surface temperature. It showed the results simulated by climate models using natural and anthropogenic forcing were consistent with recorded values.

The IPCC observed that, there are continental variations in Earth's surface warming: with North America having an increased surface temperature of approximate 0.75 degree Celsius (°C); Europe's ~ 0.75°C; South America's ~ 0.50°C; Africa's ~ 0.75°C; Asia's ~ 1.00°C; and Australia's ~0.50°C, in the year 2000. In the same year, the global average temperature anomaly was 0.70°C including global land's ~ 0.80°C and global ocean's ~ 0.55°C.



*Figure 2.1: Global Temperature Change.*

IPPC (2007): Climate change 2007- the physical science basis summary for policymakers.

The IPCC (2014, AR5), further confirmed the unequivocal warming of the climate system. Specifically, the Earth's surface temperature has become warmer, the period from 1983 to 2012 was the warmest 30-year period of the last 1400 years in the Northern Hemisphere; with global temperature (combined land and ocean surface) data calculated by a linear trend showing a warming of  $0.85^{\circ}\text{C}^2$  ( $0.65\text{-}1.06^{\circ}\text{C}^2$ ) for the period 1880-2012. According to the report, since the 1950s, the atmosphere and ocean have warmed up, the amounts of snow and ice have diminished, and the sea level has risen, and that many of these changes are unprecedented over decades to millennia.

Buildings contribution to  $\text{CO}_2$  emissions and climate change is well documented in extant literatures (Ekins and Lees, 2008; Lucon et al., 2014; Gabe, 2016). BEU accounts for more than one third of world total energy consumptions (Lucon et al., 2014; Li, Hong and Yan, 2014b), and generates between 30% and 40% of global GHGs emissions (Gabe, 2016). These studies linked CCH to energy use in buildings.

Scientific evidence (IPCC 5<sup>th</sup> AR) also, revealed that the concentration of GHGs in the atmosphere is still increasing. The recorded total annual GHG emissions (Figure 2.2), by groups of gas (HFC, PFC,  $\text{SF}_6$ ,  $\text{N}_2\text{O}$ ,  $\text{CH}_4$ ,  $\text{CO}_2$  FOLU, and  $\text{CO}_2$ - from fossil fuel & industrial process) for 1970-2010 are empirically proven. The result indicates that the GHGs atmospheric concentration increased, with anthropogenic  $\text{CO}_2$  emissions (from fossil fuel and industrial process) having the biggest contributor with an average of 58.5% share of total GHGs from 1970 to 2010; and presently put at 65% share of total GHGs emission in 2010.

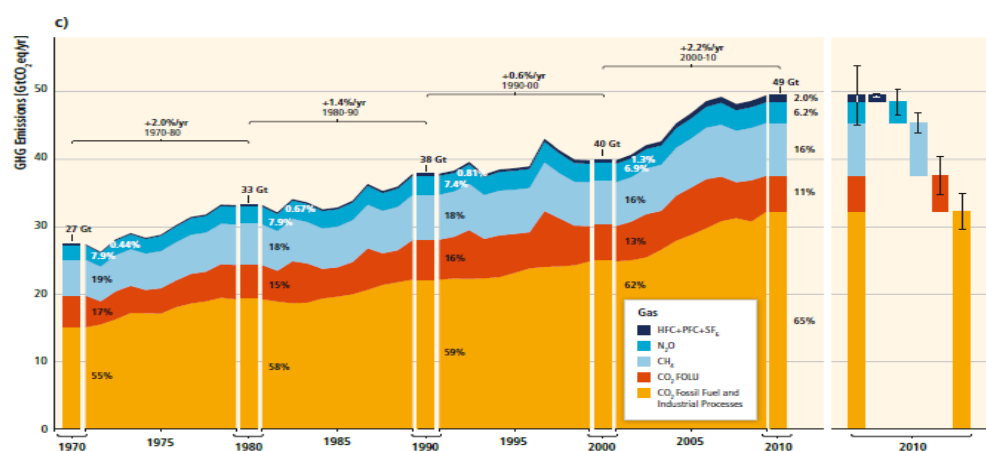


Figure 2.2: Total Annual GHG emissions by Group of Gases 1970-2010.

Including estimated uncertainties illustrated 2010 (whiskers).

Source: Working Group 111 contribution to the IPCC Fifth Assessment Report, 2014.

The IPCC (5<sup>th</sup> AR) evidence established the premise that BEU is associated with CO<sub>2</sub> and other GHG emissions. Also, it linked BEU as a major source of CO<sub>2</sub>, thus makes BEU and BEP central to global concerns and efforts at combating CCH. This might have informed the EU's energy policy action with objectives of: less GHGs, more efficiency and more renewable energy (IIEA, 2009).

Buildings play significant role in mitigating CO<sub>2</sub> emissions via: dissemination of BEE information; renewable energy resource; and BEU reduction interventions. Extant literatures (De Melo, Jannuzzi and Ferreira, 2013; Daniel and Natascha, 2014; IEA, 2014a), have made a case for BEE interventions as the critical solutions in militating against CCH. Hence, managing CCH associated risks via BEP are now a priority for national government's policies and programmes.

Smith (1997), suggested two types of interventions in mitigating global carbon emissions into the atmosphere. First, efficient management in the generation and transmission of energy production; and secondly, the efficient management of BEU through a proactive framework that will make building energy the principal target for cutting emissions of CO<sub>2</sub>. The later intervention is most worthy and important because; buildings positioning, their placement, detailed plan, building methods, and operational modalities during occupation, all have energy consumption and carbon emission implications (Ibid).

Intervention types and requirements for new construction differ from that of existing buildings. A previous study (Ibn-Mohammend, 2014), has confirmed that it will be cheaper to adapt old buildings compared to new ones. Equally, most of the existing buildings will still be standing for another 30-40years (by 2050); whilst, the rate of replacement of new buildings is only around 1-2% (Ibid).

Advantages of building's adaptation have also been highlighted in extant literatures (Altan, 2010; Ibn-Mohammend, 2014; Lee et al., 2015). Some of these are: the refurbishment of existing buildings has advantages of energy saving over new construction; adoption of EE measures and renewable technologies are best options for improvement of existing buildings; refurbishment provides lesser time and cost for owners; and could save about 15 times more CO<sub>2</sub> by 2050 compared to newer ones.

Non-domestic buildings accounts for 18% of the UK total CO<sub>2</sub> emissions. The UK Government's target plan of at least 80% carbon reduction by 2050, indicates 18% of the emission reduction must come from non-domestic buildings. Hence, the UK's strategic rollout interventions such as Displace Energy Certificates (DECs) and Energy Performance Certificates (EPCs), across the sector by 2015 (Carbon Trust, 2009), was initiated. This could be replicated in SSA and Nigeria.

Building adaptation and mitigation measures are proactive best practices against some CCH impacts. One of the means of improving BEP is to make buildings use less energy for lighting, cooling, and heating, without comprising users' comfort (Nikolaou, Kolokotsa and Stavarakakis, 2011a). Also, BEP is a strategy for sustainable utilization of building energy (Chung, 2011a), therefore, improving BEP could be achieved via embedded SSP/ SFM for existing buildings in Nigeria and the UK.

Operational FM interventions to existing building stock (BEMS, renewable, controls equipment efficiency measures, and non-technical initiatives etc.), have proven to be successful in the UK (Altan, 2010). Hence, such interventions could be adapted to Nigeria's existing building stocks. Also, delineation and dissemination of factors influencing sustainable BEU in SSA will be useful in developing an appropriate framework for improving BEP in the existing building stock. Finally, the current study reviewed the following issues in achieving the chapter's objectives: global energy production and climate change; sustainable buildings; and energy in buildings. Likewise, the chapter reviewed: methods of reducing BEU, CO<sub>2</sub> emission and improving BEP; and the business case for BEP improvement.

## 2.3 ENERGY PRODUCTION AND CLIMATE CHANGE

### 2.3.1 Global Energy Production and GHGs Emission

Global oil production increased by 12% in 2014, and is projected to be over 100 Mb/d by 2040. Likewise, global natural gas is projected to increase by 5.2 trillion cubic meter (Tcm); and coal productions by 10% by 2040 (OECD/IEA, 2015b). According to IEA, world energy demand growth is predicted to be 30% (between 2014 and 2040), and the surge in global electricity demand is projected to be more than 70% by 2040.

Previously available data (Table 2:1) confirmed that global demand for fossil-fuel energy is rising continuously. The IEA (IEA, 2009), asserts that the WPED increased from 10,018Mtoe (2000) to 12,013Mtoe (2007) with average increment of 1.5% per year. Also, the analysed data reveal a sharp rise in primary energy demand for developing countries (2007– 2030): Asia (2.9% increment), Middle East (2.8%), Latin America (1.7%), and Africa (1.4%); whilst, Europe (0.2%) and America (0.1%) show only slight increases.

*Table 2:1: World Primary Energy Demand by Region (Mtoe).*

Years	1980	2000	2007	2015	2030	2007-2030
Europe	1493	1735	1826	1788	1894	0.2%
United State	1802	2280	2337	2291	2396	0.1%
Asia	1068	2164	3346	4468	6456	2.9%
Middle east	128	378	546	702	1030	2.8%
Latin America	292	457	551	633	816	1.7%
Africa	274	449	630	716	873	1.4%
European union	N/A	1684	1757	1711	1781	0.1%
<b>World</b>	<b>7228</b>	<b>10018</b>	<b>12013</b>	<b>13488</b>	<b>16790</b>	<b>1.5%</b>

Source: IEA, (WEO 2009)

Africa's share of total energy demand is currently increasing. Her energy demand increased from 499Mtoe (in 2000) to 630Mtoe (2007); and was projected to be 716Mtoe (2015) and 873Mtoe (2030) with 1.4% average annual increment (IEA, 2009). Similar study (IEA, 2014b), confirmed that SSA energy demand increased by about 45% between 2002 and 2012; with Nigeria and South Africa having the largest share of more than 40%.

The global trend (Figure 2.3), revealed also an increase of about 60%; reaching 16.5 billion tonnes of oil equivalent; and 1.7% annual energy demand growth rate between 2002 and 2030 (WEO, 2009). Fossil fuels account for about 85% of world primary energy demand increases, just as corresponding, energy-related emissions are projected to rise by 16% by 2030.

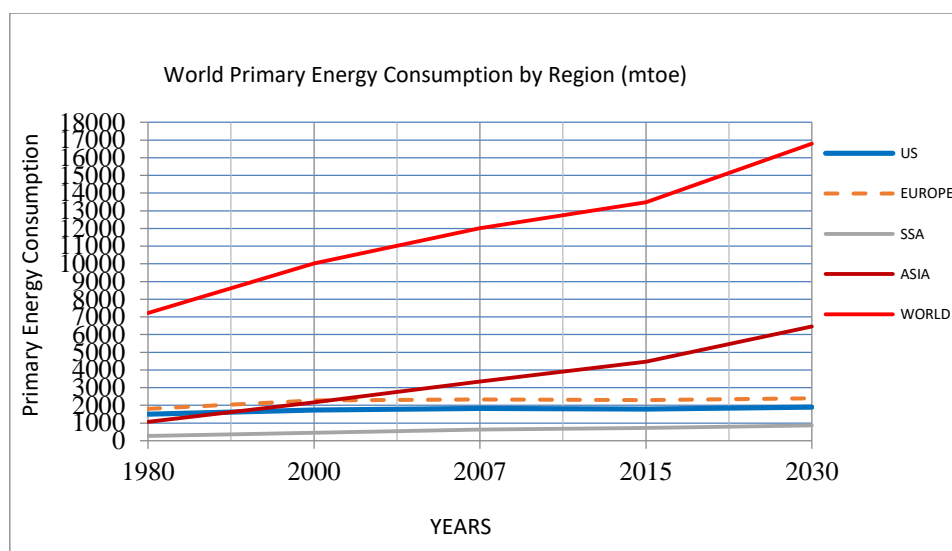


Figure 2.3: Trend of World Primary Energy Demand by Region (Mtoe)

Data Adapted from IEA (WEO, 2009).

Consequently, there is also a corresponding rise of GHGs emitted as world energy production and use accounts for two-third of global GHGs emissions (OECD/IEA, 2015a). Europe and US energy demand flatten over the period as a result of expanding the uptake of low carbon energy sources; and improved energy efficiency measures. The only exception is Asia that witness rising trend of GHGs emissions having an increment of 2.9% over the period.

The UK and Nigeria are not left out of the picture as data officially communicated in a COP21 report (UNFCCC, 2015). The report revealed that the UK's 2013 total GHGs emission stood at 575, 696GtCO<sub>2</sub>eq of which CO<sub>2</sub> was 1.55%; whilst Nigeria's 2000 GHGs emission was 212, 444 (CO<sub>2</sub> was 0.57%). This revealed UK as a higher CO<sub>2</sub> emitter compared to Nigeria, since she emits almost three times that of Nigeria.

Current data however, indicate a decoupling between the global economy and energy-related emissions. The IEA (OECD/IEA, 2015a), argued that in 2014, the global economy grew by about 3%, whilst, emissions stayed flat, and global energy intensity decreased by 2.3%. The success achieved was ascribed to increasing expansion in the growth of renewable energy usage in China, USA, Germany and Japan with nearly \$240 billion investment base. Likewise, falling costs of renewables accounted for this decoupling despite growth in the worldwide economic system.

Globally, building's share of energy-related GHGs emission increase with increases in world energy demand. Buildings accounted for about 9.18GtCO<sub>2</sub>eq of global GHGs emissions, and 19% of total global 2010 GHGs emission (Lucon et al., 2014). Past studies (IEA, 2013; IPCC AR5th; Carbon Trust 2009), also revealed that global building energy end-use of domestic and commercial buildings were 24.3PWh and 8.42PWh respectively in 2010. Similarly, based on segregation, space heating (33%) and others like IT equipment (32%) have the highest share of drivers for commercial buildings globally. While lighting (16%), water heating (12%), and cooling (7%), have moderate shares of energy end-use in buildings.

About 1.8 million UK's commercial buildings emit about 18% of her total CO<sub>2</sub> emissions/year, and 300TWh energy used annually. UK's total energy consumed 106MtCO<sub>2</sub> in 2005; and her energy end-use is driven largely by heating (46%) and lighting (23%) having the largest shares. While the use of: cooling and ventilation (11%), catering (8%), office equipment (3%), hot water (4%), and others (4%) also contribute to commercial BEU (Carbon Trust, 2009).

Energy consumption data for Nigeria's commercial building stock rarely exist. However, recent studies (Batagorawa, Hamza and Dudek, 2011; Edomah and Nwaubani, 2014), tried to disaggregate energy end-use of office buildings in Abuja (Nigeria); and projected energy demand in Lagos. Findings indicate current buildings' shares of aggregate energy demand for Lagos in 2015 are: residential (7,913MW), industrial (2,464MW), and commercial (660MW). Whilst, the disaggregated energy end-use for five office buildings in Abuja are: cooling rate (83kWh/m<sup>2</sup>), lighting rate (24kWh/m<sup>2</sup>), and appliances rate (97kWh/m<sup>2</sup>).

These studies' finding, however, are not representative of existing commercial building stock in Nigeria. Also, the findings could not account for these buildings aggregate used and disaggregate energy demand, CO<sub>2</sub> emissions and give accounts of factors that affects their energy performance.

### 2.3.2 Building Adaptation and Mitigation for Climate Change

Mitigation has been defined as a 'human intervention to resources, or enhances the sinks of GHG emissions. It is action to limit the extent of future change. Adaptation is the response to the consequences of change, which can be beforehand (anticipatory adaptation), in response to (active adaptation) or as deliberate policy (planned adaptation)' (Foxell, 2014).



Reducing CCH associated risks require instituting effective measures of different mitigation and adaptation strategies. Also, it involves actions that will prevent or reduce further a build-up of GHGs in the global atmosphere to slow the rate of change (mitigation); and making adjustment in decisions, policies and practices that consider CCH scenario (adaptation), (Aishett, 2010).

Climate change risk presents a dual challenge of mitigation and adaptation techniques to the planetary community. Hence, both strategies are needed to deal with and combat the risk of CCH. Adaptation strategies involve ensuring that buildings can cope with the anticipated impacts of CCH soon (Tymkow et al., 2013). Whilst, mitigation ensures that buildings have minimum impact on GHGs emission level.

A holistic, sustainable approach to buildings' lifecycle should be adopted to allow for future adaptability of buildings. It should be based on the concepts (Tymkow et al., 2013), of: awareness of climate change impacts, carbon mitigation and adaptation; the knowledge of the physical interrelationship between energy and materials use in buildings, carbon and environmental impacts; interconnectivity of people, engineering systems, buildings and the environment (system-type perspective); holistic whole-life approach; commitment to regulatory frameworks for cutting emissions; and team work based on collaboration and communication across stakeholders.

A successful carbon-mitigation strategy is needful for wedge stabilization of GHGs. This involves reducing building energy demand and its carbon emissions while maintain business (or domestic) activities and decent quality lifestyles within and outside the building environments. Mitigation is a strategy for limiting global warming, which involves substantial technological, economic and institutional challenges (Markovska, 2015).

Building energy demand reduction involves improvements of energy performance (increasing efficiency), and maintaining standards thereby reducing BEU. This strategy has proven to be much easier to apply to new buildings (e.g. via legislations) than existing buildings. However, there is an increasing recognition of the need to apply it to existing building stocks due to its larger share of energy demand. The existing building stock is currently the single largest source of energy use and CO<sub>2</sub> emissions in the UK. It accounts for approximately 50% of total UK

energy use with about 50% of CO<sub>2</sub> emissions been attributed to heating, cooling, lighting, and ventilation energy use in buildings (Aishett, 2010).

## I. Mitigation Strategies

Built environment mitigation strategies can be clearly classified into: reducing building energy demand (through fabric insulation & air tightness, life-cycle assessment and post occupancy evaluation); improving efficiency performance of buildings (via measurement, benchmarks & self-report, and increasing output base on the concept of more for less energy use); and decarbonising energy supply network (use of low carbon and zero/ renewable technologies) (Foxell, 2014). Human interventions in limiting global warming through BEU can only be meaningful if it involves holistic measures.

### *a) Energy Demand Reduction*

Predominantly, energy demand in buildings is required for space heating, water heating, space cooling, lighting, and appliances. In the UK, building energy demand is regulated through Part L of the building regulations (2002; 2006; 2010; and 2014) (DCLG, 2014). A recent study (DECC, 2015b), revealed the UK primary energy consumption has been declining from available data because of stringent mitigation regulatory measures. The UK's DECC, 2015 (overall energy consumption since 1970) revealed that in 2014, UK overall primary energy consumption was 193.4Mtoe, which was 6.6% and 7% lower than 2013 and 2012 levels respectively. It was recorded that the year on year decrease (2013-2014) (Figure 2.4), was the third highest since 1970. This second and first decrease was recorded as 7.3% (from 1979-1980) and 7.9% (from 2010-2011).

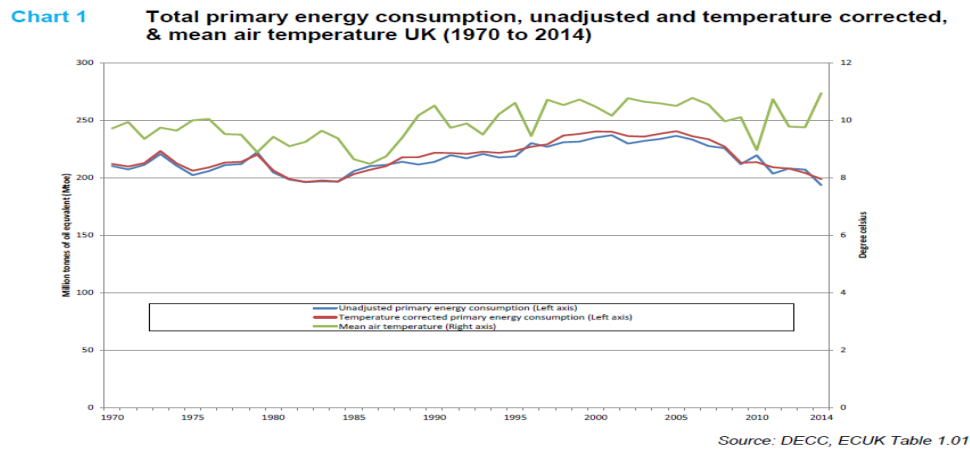


Figure 2.4: UK Total Primary Energy Consumption & mean Temperature.

Based on normalised data for temperature adjustment basis (removing the impact a hot or cold weather has on energy consumption), UK energy consumption dropped by 5.3Mtoe (6%) to 198.2Mtoe in 2014. This has been the lowest since 1980, while the mean air temperature of 10.9<sup>0</sup>C recorded in the same year (2014) was the warmest since 1970 (DECC, 2015b).

The current data support the use of building regulations to reduce energy demand. Since the 2002 revisions to part L of the building Regulations, more stringent requirements have been placed on building design, construction and operation through subsequent revisions. The 2010 revision required an improvement of 40% on the 2002 benchmark for energy efficiency standard, while the 2014 revision upgraded the requirement by a further 6%.

#### *b) Life-cycle Assessment*

Some studies (Ibn-Mohammend, 2014; Chau, Leung and Ng, 2015), have described Life-cycle energy assessment as the consideration of the capital energy input into a building (embodied energy) and its operational energy inputs or requirements. The life-cycle energy demand of a building is therefore, the energy required for development and construction of the building (embodied or capital energy); and energy required in the operational running of the building including refurbishment and demolition (operational energy).

The same definition applies to the life-cycle CO<sub>2</sub> emissions estimate of the building (building's life-cycle carbon footprint). The conversion method is through the application of energy-carbon conversion factor per scenario visa-vice. The energy demand of a building requires a holistic assessment for comprehensive quantification of its energy potential for a reduction.

These studies (Ibid), classified the phases involved in the life-cycle emissions of a building into; embodied, operational, disposal and recycling after end of life utilisation. The embodied emissions are linked to the energy utilized in the process of making the product. This involves energy used to create the building products, build it and demolition it (Figure 2.5).

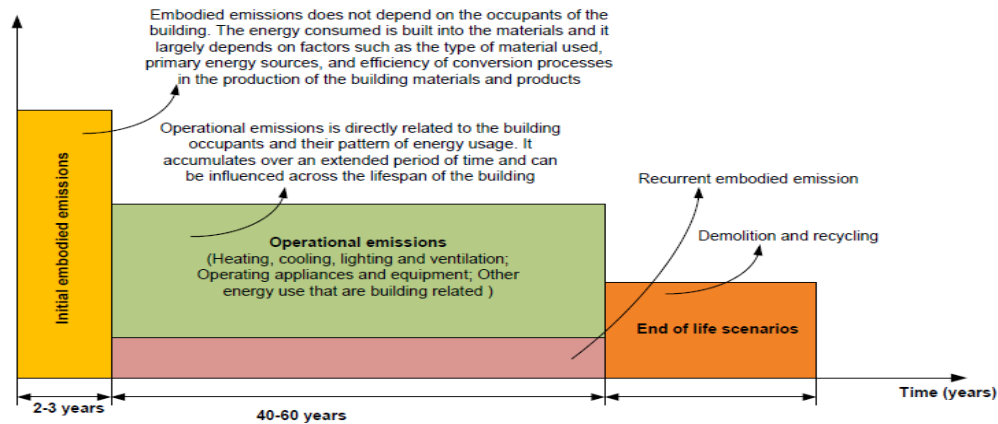


Figure 2.5: Lifecycle emissions component of a typical building.  
Source: Ibn-Mohammed (2014).

The emissions associated with the energy utilized during the building operation phase are known as operational emissions, which are carbon dioxide equivalent of the energy use for running HVAC services, lighting and other contrivances. While disposal and recycling emissions are the energy required for demolishing the building, and the waste transportation, energy at the end of the life span of the building (Ibn-Mohammend, 2014; Chau, Leung and Ng, 2015).

Whole-life-cycle emission of a building is the sum of the embodied emissions, operational emissions, emissions associated with maintenance and materials replacement including component replacement as well as emissions from recycling of waste from that building demolition (Iyer-Raniga and Wong, 2012; Ibn-Mohammend, 2014).

### c) Post-Occupancy Evaluation (POE)

Post-Occupancy Evaluation (POE), has been defined as the process of getting feedback on the performance of a building during its operational life cycle phase from the occupants (BRE, 2017). Improving overall BEP to mitigate against climate change, calls for building owners, facilities directors and other operators getting rapid feedback from users to identify opportunities and pitfalls. But, this does not frequently occur, making it important for the use

of post occupancy evaluation as a strategic climate mitigation tool. Hence, Foxell (2014), suggested that information on demand from building users, and the building use of energy can only be obtained through measuring the building in occupation.

Several studies (Bordass et al., 2001; Bordass and Leaman, 2005; Leaman, Stevenson and Bordass, 2010; Roberts, 2014), have employed POE in investigating the energy performances of existing office buildings. The tool has been shown to be useful in technical and non-technical probe of existing buildings. The studies reiterated the importance of POE as an absolute tool for ensuring feedback from occupants and operators on building performance. Hence, its global acceptance as a valuable tool for improvement of existing buildings; and its help to inform the design and operational decisions by revealing avoidable common pitfalls and implementable successes (Tymkow et al., 2013).

POE originated in the UK with its emergence from the trends towards science based building in the 1950s and 1960s. The Royal Institute of British Architect introduced Stage M: Feedback in its published plan of work in a RIBA first handbook for the design team operation in 1963. RIBA withdrew it from its publication in RIBA, 1973, because they felt architects could not bear the associated cost of post-occupancy evaluations (Roberts, 2014). Also, based on the theory of operational research, the environmental psychologist started its use in the 1970s in studying how buildings affect people, but was later abandoned due to dissatisfaction with its uses, (Tymkow et al., 2013).

Notwithstanding, in 1994, the UK government through the department of trade and Industry (DTI), embraced the use of POE by sponsorship of research project tagged “Post-occupancy Review of Buildings and Engineering” aka “PROBE”. The Probe studies performed POEs on 20 UK low energy buildings between 1995 and 2002, (Tymkow et al., 2013; Roberts, 2014). Furthermore, subject fields have examined the barriers and drivers for the use of POE. They all argued that the construction industry’s structure and obligations often end at practical completion. Since, POE is an ‘aftercare’ service, it is impossible to enforce or impose POE on the design or construction team. Also, POE is an element of service, which traditionally does not exist and with a relatively modest impact, impede POEs as a strategic mitigation tool amongst other barriers.

It has been argued (BRE, 2017), that many building performance falls short of planned expectation, which impact on building, running costs, staff and client dissatisfaction and performance, health, safety and comfort. Likewise, the value of POE has become significantly recognised globally, as it helps reveals impacts of building poor performance on operating cost, user's well-being and business efficiency (Ibid). Other identified drivers for the use of POE are: rapid feedback from the use of POE is quicker than other research routes in terms of quicker reaction to problems' resolution; and good results from the use of POE can be marketed effectively, etc. (Tymkow et al., 2013).

The realisation of importance of the BAM, made the UK introduced the Government's Soft Landing (GSL) and mandatory Building Information Modelling Level2 (BIM L2) schemes, for all publicly funded buildings having over 2000m<sup>2</sup> on 1<sup>st</sup> April 2016, (BRE, 2017; Brittain J., 2017). This inevitably made POE requirement mandatory for most public buildings. The Schemes ensure that all public buildings must meet the requirements of soft landings and POE that requires feedback; and data be stored on the asset BIM (Brittain J., 2017; Gary Clark, 2016; BUILDUP, 2016).

#### i. Government Soft Landings

Some authors (Brittain J., 2017; Clark, 2016; Tiemey and Tenant, 2016, etc.), elucidated that, the Government Soft Landings predominantly require the project team to establish key performance indicators (such as energy use, occupant satisfaction, capital and running costs, and ranges of functional metrics based on the building types and activity); track these KPI from design, construction and to operation phase; and verify if these have been achieved during building operation. Particularly, Brittain (2017) emphasised that the schemes led to the inclusion of stages 6 (Handover) and 7 (In Use) in the Royal Institute of British Architect (RIBA) Plan of Work, and need for the creation of a handover strategy from stages 1 to 7.

The central guiding principle of the Soft Landings policy is early involvement of the end-user as government's (client's) commitment to aftercare post-construction (BUILDUP, 2016). It is about early User and Facilities Manager's involvement in the project design. As, it was developed by the Cabinet Office with the aim of cutting down by 20% the capital cost and running of Government funded public buildings, and aid in reducing energy and CO<sub>2</sub> emissions (Brittain, 2017). Since its inception, the awareness and recognition of the importance of POE

is increasing; and public funding bodies (such as the Scottish funding Council, Scotland Local Authorities etc.) have made POE compulsory on building projects they funded, including the implementation of POE on new schools (Ibid).

## ii. Building Information Modelling (BIM)

The National BIM standard (NBIMS) (2006) cited in Barlish K., 2011.), defined BIM as “a digital representation of physical and functional characteristics of a facility. Therefore, it serves as shares knowledge resource for information about a facility, which formed a reliable basis for decisions during its lifecycle from inception onward. The BIM is a shared digital representation founded on open standards for interoperability”.

It is a computer-based process that used design to understand and demonstrate the key physical and functional characteristics of a building on a virtual computerised model basis, (BIS Gov., 2015; Barnes and Davies, 2014). BIM used computer software model to stimulate building design, construction and operation resulting in a ‘building information model’ for information management purposes (Barnes and Davies, 2014). The information usually presented in 3D model virtual is contained in a computer software database for data classification, analysing, reporting and exporting. The database contains all architectural, engineering and other design, construction and operation information.

The use of BIM is new and is fast evolving in the construction sector in the UK. The UK Government’s Construction Strategy 2011, mandated that by 2016, all government construction projects procured centrally to be fully BIM compliance, (Barnes and Davies, 2014). The UK BIS BIM Strategy is currently the most ambitious and advance centrally driven programme in the world (BIS Gov., 2015). UK’s HM sees BIM as a collaborative way of working underpinned by digital technologies which unravel more efficient ways and means of designing, creating and maintaining assets. UK’s HM described it as a game-changing ICT and cultural process for the construction sector; and assert that it embeds key Product, asset data and 3D computer model useful for effective management information throughout a project lifecycle.

Extant literatures (BIS Gov., 2015; Barnes and Davies, 2014; Chuck et al., 2011), have cited other merits of BIM that include: BIM brings in more intelligence and greater efficiency;

increased performance and quality of building; improved EE and sustainability of buildings; improved commissioning and handover of facilities information; better management and operation of facilities; capable of being integrated with operations and FM systems; BIM process has helped tailor IT to the specific needs of the construction and civil engineering industries; and its adoption for the design and construction process, help to achieve smoother and systematic coordination and use of all available data etc.

Currently, based on the Bew and Richard Model developed in 2008 (Figure 2.6), BIM contains four levels (Stroma, 2017), mainly: the pre-BIM era (BIM Level 0, pre-2011) that involved CAD in 2D drawings, where there is no collaboration; BIM Level 1 (2011), which involved models and Objects (CAD & BIM) based on 2D or 3D where little collaboration exists; BIM Level 2, present stage (2016), where the Government made it mandatory for all public funded building to be incorporated with BIM, and collaboration on a single data source that aids the production of a federated BIM Model; and the BIM Level 3 (future Open BIM, known as the universal approach to built asset data), where targets are yet to be defined by the Government for integrated interoperable data process for life cycle management as displayed in the BIM maturity (in figure below??).

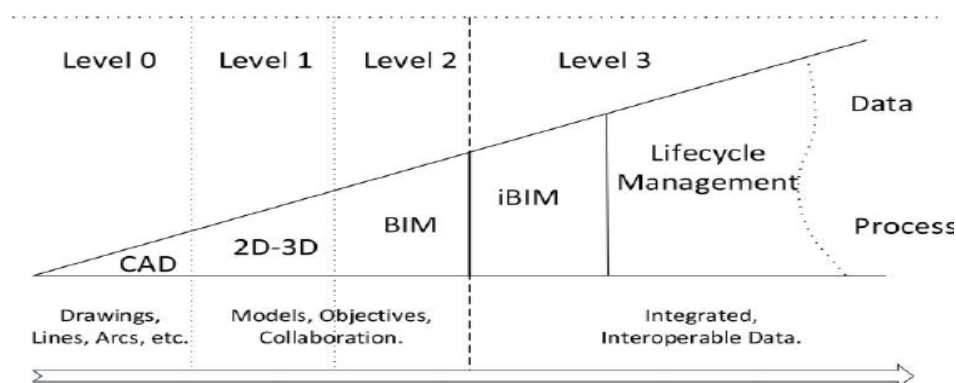


Figure 2.6: Bew and Richard BIM maturity Model  
(Bew and Richard, 2008; 2010)

The UK Government Construction Client Group (GCCG, 2011), however, adopted the Mark Bew and Mervyn Richard model and transformed it into the UK's BIM maturity model or iBIM model or the BIM wedge due to its famous shape (Figure 2.7), (BIMthinkSpace, 2015).



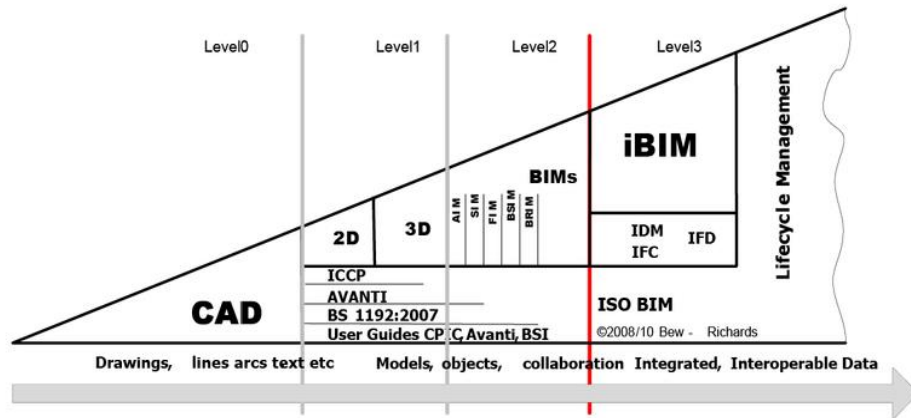


Figure 2.7: The UK BIM Maturity Model  
(GCCG, 2011)

Since, its conception, the UK BIM maturity model is central to all Government's UK-centric construction strategies (Soft Landing, Work flows by RIBA Plan of Works, Roles in information Managers and Protocol). However, the Model was criticised for its levels not being able to assess BIM performance within organisation amongst others. Thus, it could be described as strategy model or road map or policy model rather than maturity model (BIMthinkSpace, 2015).

## II. Adaptation Strategies

Some authors (Douglas, 2006; Akande, 2015), have postulated that adaptation is an active strategy for improving the sustainability of existing buildings with the potential of extending their life span. Adaptation is an effective strategy for improving the energy performance of existing buildings. Others (Yudelso, 2009; Akande, 2015), argued that most buildings (about 75%), which are expected to be functioning and will still be in-use by 2040, have been constructed. Consequently, building professionals are tasked with the responsibility of providing sustainable and energy efficient refurbishment of existing buildings. This can only be achieved through adapting and retrofitting of existing buildings to the optimum energy efficiency standard.

In the UK, existing stock building stock accounts for about 50% of the energy use and about 50% of the total carbon emissions, which are attributed to HVAC energy use in buildings (Aishett, 2010). The UK's ambitious plan of reducing the built environment, carbon emissions by up to a target of 11.7 million tonnes per year by 2020 is a promising adaptive strategy.

Improvement of existing building stocks through refurbishment will help achieve the aim of delivering low carbon buildings.

Past studies (Altan, 2010; Remøy and Wilkinson, 2012; Foxell, 2014), have shown that adaptation of buildings improve BEP and reduces GHGs emissions. Fabric upgrades as retrofit measures: increased insulation and airtightness improvement, efficient ventilation, new heating controls, upgrade of windows, low-energy lighting, and replacement of old appliance with energy-efficient upgrades have proven to be successful at improving BEP and reducing CO<sub>2</sub> emissions in the past.

The success of service upgrades such as: replacement lighting and heating systems, improved controls, incorporation of renewable energy mix of PV panels and solar thermal installations have recorded energy saving of 5.0- 46.0% (Altan, 2010; Ma et al., 2012; Gabe, 2016). Also, the practice of EE behaviour in buildings, and good natural daylight with minimum artificial light requirement, employing technologies such as sensors for lighting control, thermostats, BEMS and smart meters for identifying unnecessary and excessive usage, have shown to help save up to 60% energy used in buildings (Ma et al., 2012; Gabe, 2016).

### 2.3.3 UK Government Actions

The UK has both international and domestic GHGs reduction targets, namely: Kyoto Protocol; the Climate Change Act 2008; and EU Effort Sharing Decision, (DECC, 2015a). The British government launched the UK Climate Change Programme in 2000 with the aim of cutting GHG emissions in the country (DEFRA, 2009). Since the establishment of the climate act in 2008, the UK has made significant efforts putting in place successful plans and programmes actioned towards curtaining further emission of GHGs. Under the Climate act 2008, the UK planned to cut her emissions by a third by 2020 and at least by 80% in 2050 compared with the 1990 level (base year). This made the UK the first country in the world to have a ‘greenhouse gas budget’ (DEFRA, 2009).

DECC (2015), upheld the assertion of DEFRA by claiming that, the UK Climate Change Act 2008 is a long term legally-binding framework to reduce GHG emissions. It commits the UK to reducing emissions by 80% below 1990 baseline by 2050 including interim target of 34%

GHG emissions reduction by 2020. However, there was a difference in the claim for the interim target for GHG emissions by 2020. While Defra claimed a third (26%), DECC quoted 34% as targets. Further analysis revealed that the UK actual interim target for 2020 is 20% of the 1990 level as contained in the Climate and Energy Package 2009 legislation.

In the Climate Change Act 2008, the UK government set the first three carbon budgets in May 2009, covering the periods of 2008-2012, 2013-2017 and 2018-2022. While the fourth carbon budget, 2023-2027 with a 50% GHG emission reduction below the 1999 level was set in June 2011, (DECC, 2015a). The UK's four carbon budgets and their equivalent average annual levels are shown in Table 2:2.

*Table 2:2: Summary of UK's Carbon Budgets. UK only, 2008-2027.*

	MtCO <sub>2</sub> e			
	Budget 1	Budget 2	Budget 3	Budget 4
	2008-12	2013-17	2018-22	2023-27
Budget level	3,018	2,782	2,544	1,950
Equivalent average annual emissions	603.6	556.4	508.8	390.0

Source: Carbon Budgets.

<https://www.gov.uk/government/policies/reducing-the-uk-s-greenhouse-gas-emissions-by-80-by-2050/supporting-pages/carbon-budgets>

Note: The levels of carbon budgets are not shown here as a percentage reduction from the base year. This is because the base year figure is not fixed, but is revised each year to incorporate revisions to the inventory so the percentage reduction required to meet targets will change over time.

Source: Department of Energy and Climate Change: Adapted from UK progress towards GHG emissions reduction targets. Statistical release: Official Statistics, 19<sup>th</sup> March 2015.

The UK's Kyoto protocol target, under the first commitment period (2008-2012), UK recorded 603.6million tonnes CO<sub>2</sub> equivalent per year (MtCO<sub>2</sub>eq/year). UK succeeded in achieving 12.5% reduction in base year emissions (target set based on 1990 baseline), and 22% lower than base year emissions on the net of EU emissions Trading System (EU ETS) trading. Target has not been set for the second commitment period (2013-2020) (DECC, 2015a).

Table 2:3: Progress towards UK Carbon Budgets. UK only, 2008-2013.

	2008	2009	2010	2011	2012	2013
All greenhouse gases (including net emissions/removals from LULUCF) without allowance for EU ETS	635.9	582.5	598.0	554.9	573.5	566.5
EU ETS Net UK purchases/(sales)	20.2	(12.6)	(6.7)	(24.0)	(13.6)	43.8
All greenhouse gases (including net emissions/removals from LULUCF)	615.7	595.2	604.7	579.0	587.1	522.7

Source: Department of Energy and Climate Change: Adapted from UK progress towards GHG emissions reduction targets. Statistical release: Official Statistics, 19<sup>th</sup> March 2015.

The UK met her commitment for the first carbon budget (2008-2012). Her emission was 36 MtCO<sub>2</sub>e below the cap of 3,018 MtCO<sub>2</sub>e over the first carbon budget period. Also, UK GHG emissions for 2013 was 522.7MtCO<sub>2</sub>e (Table 2:3 above), which was 33.7MtCO<sub>2</sub>e below the average annual emissions of 556.4 MtCO<sub>2</sub>e required to meet the second carbon budget (2013-2017) (DECC, 2015a).

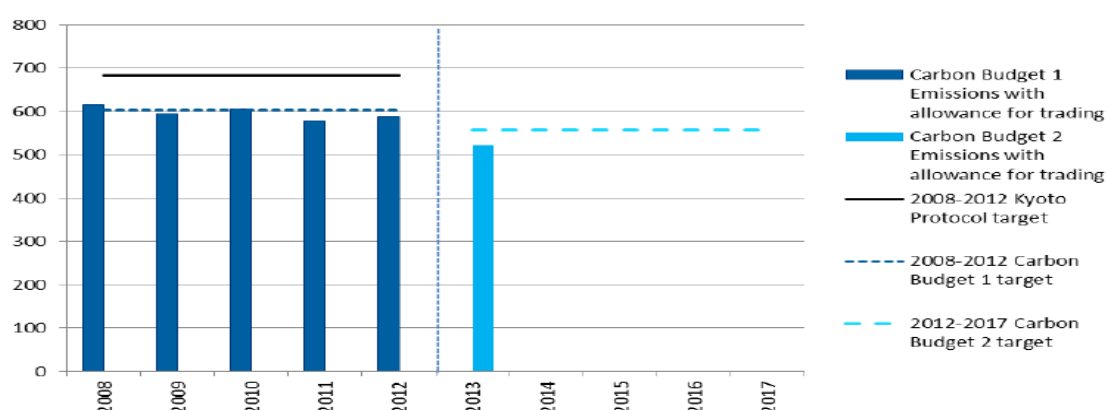


Figure 2.8: UK's progress towards meeting Kyoto Protocol & Carbon Budget targets.

Source: DECC: Adapted from UK progress towards GHG emissions reduction targets. Statistical release: Official Statistics, 19<sup>th</sup> March 2015.

The government also established the UK Climate Impact Programme (UKCIP02) in 2002 and UK climate Change Project (UKCP09) in 2009. The climate change projects are important steps toward improving understanding of our complex climate. They represent strong and credible climate science. The government plan for tracking climate change is based preparation for the future, such as changing the way we build and refurbish our houses and infrastructure and developing innovative ways of doing business amongst four principles (DEFRA, 2009).

The climate change risk response is a collective response. The UK has so far made progress towards this response through: combined legislations, policies, programmes and signing of several international protocols (commitments) on Kyoto gases (GHGs). These efforts are already yielding desired results based on the declining GHGs emission rates of UK from available data (Figure 2.8 above). Hence, SSA countries like Nigeria could learn from the UK's exemplary actions. The regional governments in SSA (both as individual or collective) can undertake similar measures to reduce the emission of GHGs to slow down global warming; and at the same time responds to the predicted impacts of climate change.

## 2.4 SUSTAINABILITY AND SUSTAINABLE BUILDINGS

### 2.4.1 Sustainability and Sustainable Development (SD)

Globally, the built environment is now strongly linked to GHGs especially CO<sub>2</sub> emission; as it accounts for 35.40% of world energy consumption and 40% of global GHG emissions. It also accounted for 40-50% share of the 49.5GtCO<sub>2</sub>eq of GHGs emission in 2010 (Victor et al., 2014). This earned the sector, particularly building, the focus of sustainable development (SD) through campaigns and awareness of energy efficiency and zero carbon emission (Schlör, Fischer and Hake, 2012).

Between 2000 and 2010, fossil-fuel base CO<sub>2</sub> accounted for 62-65% of the global GHGs emission (Lucon et al., 2014). This heightened growth in exploration, development and production of fossil fuel caused severe damage to our environment that finally turned a global issue since the 1970s. The environmental damage caused by the fossil-fuel energy system brought the first mention of the concept of SD in United Nation's Environmental Conference (UNEC), in Stockholm (UN, 1972). Thus, in 1982, the United Nation General Assembly World Charter for Nature used the term 'Sustainability' for the first time (Schlör, Fischer and Hake, 2012).

The UNEC in Stockholm (1972), focused on the SD of natural biodiversity. There was agreement on the preservation of natural habitat to make a sustainable improved living conditions for all; and international cooperation to accomplish it. Likewise, the conference laid foundation for the founding of the United Nation Environmental Programme (UNEP), in Nairobi, Kenya and the international monitory organisation, Earth Watch. The conference

emphasis was to achieve a way of solving environmental problems with considerations to social, economic and development policy factors (ARE, 2015).

Nevertheless, global consciousness and concerns were conveyed to the fore by the works of: Rachel Carson's 'Silent Spring' (1962); Garret Harden's 'Tragedy of the Commons' (1968); Ecologist magazine's article 'Blue Print for Survival' (1972); and the Club of Rome's 'Limits to Growth' report (1972). These works underpinned the basis of the research on which 'our common future' report was published (UK SDC, 2011).

The World Commission on Environment and Development (WCED), carried out its study in mid 1980s; and published the Brundtland Report "Our Common Future" named after the chairperson Gro Harlem Brundtland in 1987. "Our Common Future" laid the conceptual foundation for the concept of sustainable development. The Brundtland Report (WCED, 1987) defined sustainable development (SD), as:

*"Development which meets the present needs of today's generation without endangering the opportunities of future generations to meet their own needs"*

The report recognised system boundaries and implied limits. Particularly, it recognises the limits imposed by technology and social formation of environmental resources; and the ability of the biosphere to absorb the impacts of human actions. The report concludes that technology and social organisations can be managed and improved to make way for a new era of economic development. According to (Schlör, Fischer and Hake, 2012), the commission expressed the important of energy system for the realisation of SD, which accelerated the global discussion on the future of fossil fuel-based energy system and the meaning of global energy governance in the context of climate change.

Since the Brundtland report in 1987, there have been a series of misconceptions and interpretation of the meaning of SD. Nevertheless, it was the UN 1987 conference report by the WCED that clarified the ambiguity surrounding the meaning of SD.

The 1987 UN's official report (WCED, 1987), on SD (pp38) defined it as:

*“A process of change in which the exploitation of resources, the direction of investment, the orientation of technological development, and institutional changes are all in harmony and hence both current and future potential to meet human needs and aspirations”*

The UN’s report also clarified the concept of SD as meaning thus:

- Meeting the need of everyone and giving them equal opportunity to satisfy their aspirations to a better life
- Perceived needs are determined based on social and cultural values; therefore, SD requires the promotion of values that encourage consumption standards that are within ecological boundaries
- SD requires that societies meet human needs through increasing productive potential and ensuring equitable opportunities for all; etc.

The concept of SD as explained in the UN’s report (Ibid), is a holistic approach for integrated global policy strategy based on intra- and intergenerational ethical considerations. It integrates ecological, social and economic sustainable goals at national and international levels. As it provides the basis for the science of sustainability and development of the political and institutional framework of sustainability, it removed the limit imposed by the ambiguity on the extent to which countries could exploit natural resources for developments based on the Brundtland definition. Thus, clarifies it by using ‘harmony’ as the gold standard for measuring sustainability of development activities.

The strategic requirement for SD as contained in the report hinges on: meeting human basic needs; conservation and enhancement of earth capital; revitalising and changing the quality of growth; technological re-orientation and risk management; maintaining sustainable population growth; and consideration of combined environmental and economic criteria in decision making. Nevertheless, since Rio de Janeiro 1990’s conference, several authors have criticised and redefined sustainability in their own understanding based on the publication of the Brundtland’s report (Ibid).

Smith (1997), asserts that Sustainability defined on WCED, 1987 p. 43 is inadequate, as our planet as inherited by present generation is already in unsustainable condition. Therefore, we need a definition which recognizes the scale of the threat facing future generations, According to them, David Pearce’s two approach to sustainability seems to be the best suitable definition,

which he calls ‘Weak’ and ‘strong’ sustainability. Weak sustainability is when the sum of capital stock we pass to the next generation remains constant.

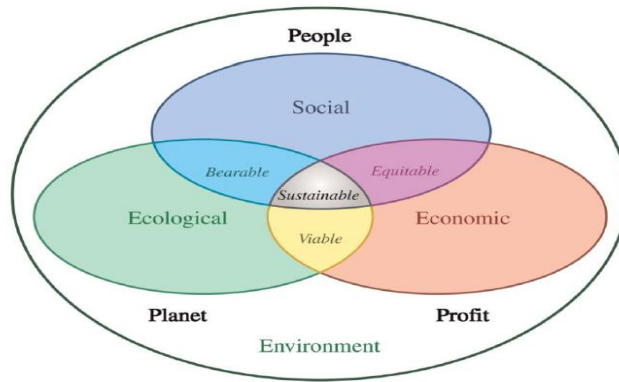
In this definition, depletion of Natural capital or critical natural resources like soil, biodiversity, the hydrological and carbon cycles, and the ozone layers can replace or be compensated for by an increased man-made asset like buildings, road, other infrastructural facilities and machinery. David Pearce defined ‘strong’ sustainability as ecological assets that cannot be replaced by man-made artefacts. This, to them means, preserving critical natural capital and forgetting (or not considering) the benefits they can generate. They supported adoption of strong sustainability as the only, but difficult means of saving our planet from the consequences of the population explosion and global warming.

#### 2.4.2 Sustainable Development: Conceptual Trend

SD as defined in the Brundtland report (UN 1987), is underpinned traditionally, by environmental, social and economic dimensions as the three pillars of sustainability. Hence, Sustainable development is regarded as the best trade-off between these three pillars that craves for greater compatibility (Mateus and Bragança, 2011; Awalh, 2017). The attempt to seek for a just and balance interrelationship and dependency between the three sustainability concepts, also underpinned the basis of several developed sustainable rating systems globally. These elements in a sustainable model are best considered to interact with each other, while their relationship leads to shared sustainability goals expressed by viability, variable and equity (Ali-Toudert, and Ji, 2017).

The recent work of Lovisa (Lovisa, 2014), based on the ‘three pillar’ (Lehtonen, 2004) and ‘doughnut’ (Raworth, 2012) models makes more meaning on the linkage between sustainability, resources usage and development. They all opined that the concept of sustainable development is based on the interaction and interrelationship between the economic, environmental (ecological) and social sustainability. Stevens et al 2003 and Lovisa views based on ‘Three Pillars’ model (Figure 2.9), considered sustainable economic based on policy guidance for dynamic efficiency and intergenerational equity.





Source: Thomsen & van der Flier 2009

*Figure 2.9: 'Three Pillar' Model of Sustainable Development.*  
(Lovisa, 2014)

They assert that sustainability is when an economy is working at the level of dynamic efficiency by maximizing social utility; exerting “non-wastefulness”; and ensuring that the total welfare function is non-declining overtime for the pursuit of intergenerational transfer, the economy has the fulfil intergenerational equity condition. The ‘three pillars’ depicts the dynamic interactions between the three sustainability constructs (social, ecology and economy), the main activity factors (people, planet and profit) and the environment. A balance is struck (sustainable) when a development is viable, bearable and equitable.

Lovisa also cited the work of Raworth’s, ‘Doughnut model: a safe and just space for Humanity to Strive’. Raworth’s Doughnut model is an analytical framework, which suggests that earth natural resources set environmental boundaries with a ceiling for human activities. Raworth and Lovisa, (Figure 2.10), opined that it includes the pursuit of a just space free from critical human deprivation. In definite sense, SD means living within ecological and social margins in escaping the ecological and social crisis. Raworth’s conceptualised social foundation, safe & just space for humanity, and ecological boundaries in a ‘doughnut shape-framework’ also shown in Figure 2.10.



Source: Raworth 2012

Figure 2.10: 'Doughnut model: a safe and just space for Humanity to Strive'.  
Adapted from: Raworth, 2012; 'Doughnut model; Lovisa, 2014.

In the 'doughnut' model, the boundaries are guided by research, based on norms, and consist of entire systems that are interconnected on a global scale. Social sustainability is realized when social foundation is built within ecological limits. Lovisa (2014), claims the doughnut model place a stringent demand on human activities, as it does not allow for trade-offs between extents that risk cross tipping points of Earth-system process. Also, it came with the dual aims of moving human population back to a safe environment space as well as moving it forward into a just space.

A paradigm shift now includes culture (Hawks, 2001; NZMC, 2006; Higgins, 2015) and governances (Lozano, 2008; Valentin, A., and Spangenberg, J.H., 2000), as new disputed additional concepts of sustainability as the fourth pillar by their different proponents. The culture's vitality is seeking for human wellbeing, creativity, identity and diversity in their habitable environment. While governance is management, decision-making, policy and institutional responsibility requires in achieving sustainable development (Ali-Toudert and Ji, 2017).

Ali-Toudert and Ji, (2017), reviewed the existing sustainability models based on the old and the new paradigms. He classified the previous models underpinned by the fundamental concepts of Environment, Social and Economic as old (Klein, 2009; Spindler, 2011); and the newly evolving models based on addition of culture to the three sustainability concepts as a new paradigm (Hawks, 2001; NZMC, 2006; Higgins, 2015). Whilst, Ameen, Mourshed and Li (2015), argued that the recognition of the impact of the built cultural heritage on social

wellbeing of different population groups within towns and cities as an important dimension of SD, brought its fundamental parts to four: environment, social, economic and culture.

The RIO +20 declaration (SDKP, 2017), re-affirmed the acknowledgment of the natural and cultural diversity of the world; and recognises the critical contribution of culture and civilization to SD in achieving a just balance among the economic, social and environmental needs of present and future generations necessary to promote harmony with nature. Consequently, the current study opined that the cultural vitality (wellbeing, heritage and innovation) should be added as the fourth pillar of SD (Ali-Toudert and Ji; 2017); and should be differentiated from the social construct (justice, inclusion and human rights) in achieving sustainable BEP management. Also, governance and institution play key role in corporate social responsibility towards SD. Hence, the institution could be aligned as corporate individuals within the concept of environment, social, economic and cultural as four pillars of SD.

Interestingly, social sustainability based on social capabilities and social capital has been achieved by developed nations. Whereas, the developing countries like Nigeria, are yet striving to attain social sustainability. The UK has more substantial social capital (norms, trust and trade-off) that speed up the efficiency of society than Nigeria. Hence, the UK possesses greater adaptive capability to convert economic wealth into desired outcomes such as climate change risks mitigation and adaptation strategies.

The attainment of economic sustainability defined as, the maintenance of capital for continuous generation of income with consideration for social costs and benefits (Lovisa, 2014), is marred with several barriers (sharp practices, nepotisms, lack of patriotism, etc.) in the developing SSA countries than in developed countries. Hence the ability for these nations to recognize the association of economic evolution, energy usage, CO<sub>2</sub> emissions, and climate change with might be lacking.

#### 2.4.3 Global actions on SD and Climate Change

The concept of SD has evolved and continues to metamorphose into several international accords, consensus, and UN's resolutions on climate change and SD (compiled in Appendixes 1A-1B). The relationship between climate change and SD has also been established and

enhanced, as the two concepts have taken centre stage at international discourses. This has led to several UN international conferences of parties (COPs) since 1987; including implementation of the UNFCCC in 2002.

It was at the Vienna convention (22nd March 1985) that accord was signed on the protection of the ozone layer. It was a precursor to the 1987 Montreal protocol on substances that depleted the ozone layer, which was adopted on 16<sup>th</sup> September 1987 (UNEP, 2004). Consequently, meetings of party to the 1987 Montreal Protocol took place afterward. The London amendment of 10<sup>th</sup> August 1990; the Copenhagen amendment 14<sup>th</sup> June 1992; the Montreal amendment of 10<sup>th</sup> November 1997; and the Beijing amendment 25<sup>th</sup> February 2002, held amongst others.

The first Conference on Environment and Development (UNCED) ‘Earth summit’ in 1992 held in Rio de Janeiro, where Agenda 21 was adopted (UN, 1992). The Rio de Janeiro 1992 conference allowed governments to develop SD indicators and goals. This was underpinned by the establishment of the Commission for Sustainable Development (CSD). The CSD was responsible for developing indicators for the measurement of SD and monitory tools.

The fundamental outcome of the conference was the accord that protections of the environment, social and economic development are fundamental elements of SD based on the principle of Agenda 21. The ‘Earth summit’ facilitated adoption of the Kyoto Protocol established at the COP3 in 1997 held in Japan on 11<sup>th</sup> December 1997. It was the world’s first collaborative initiative to try to reduce carbon emissions on a global scale. The key outcome of the protocol sets binding targets for 37 industrialised countries and the European community for reducing GHG emissions. It also committed themselves to benchmarking allowable emissions against the 1990 emission levels (UNFCCC, 2012).

In pursuance of the sustainability agenda and climate change actions, the COP through the UNFCCC have achieved several successes since 1995 to date (Appendixes 1A & 1B). The tables contained details of all the COPs (from COP1 to COP16) with successes and failure recorded to date. The first COP1 (in Berlin, 1995), laid the foundation for the negotiation that strengthen commitments on SD and climate change from developed countries.

At the United Nations Climate Summits on Climate Change by Conference of Party (COP14) in Poznan, Poland (December 2008); and COP15 in Copenhagen, Denmark (December 2009), ministers failed to reach agreement on binding emission targets (UNFCCC, 2014). However, successes were recorded with the Doha's COP 18 in Qatar (December 2012), where the Doha's amendment to the Kyoto protocol was adopted (Ibid). It committed the parties to a 2<sup>nd</sup> commitment period from 2013 to 2020. Another success recorded with recently concluded Paris' COP 16, in France. About 195 countries agreed to combat climate change and to release actions and investment towards a low carbon, resilient and sustainable future (UNFCCC, 2015).

#### 2.4.4 The 2030 Agenda for Sustainable Development

In January 2016, the UN launched the implementation of the 2030 Agenda for Sustainable Development based on adoption of the 17 Sustainable Development Goals (SDGs). The seventeen SD goals and 164 targets proposed by the Open Working Group in December 2013, was based the UN's eight anti-poverty Millennium Development Goals (MDGs between 2000 and 2015 (Appendix2). This was adopted by 193 heads of state and other world leaders to wipe out poverty, fight inequality and tackle climate change by 2030 (UN, 2015). Amongst the seventeen goals (Appendix3A-3B), were the 7th and the 13th goals that are significantly related to this current study.

The UN focuses on ensuring access to affordable, reliable, and modern energy for all via Goal7. The goal set specific targets that must be accomplished by 2030: ensure universal access to affordable, reliable and modern energy service; increase substantially the share of renewable energy in the share of global energy mix; double global rate of improvement in energy efficiency; enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, EE, and advance cleaner and fossil technologies, and promote investment in energy infrastructure and clean energy technologies; etc., (SDKP, 2017).

Goal13 targets integrate climate change measures into national policies, strategies, and planning; improve education, awareness raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning amongst others

(Ibid). Finally, these goals were underpinned by the 7th goal of the 2000-2015 millennium development goals agenda that bothered on ensuring environmental sustainability.

#### 2.4.5 Improving the Sustainability of Existing Buildings

Globally, buildings are sustainable if they are efficient to operate and satisfied the purpose for their use (Yudelso, 2009). Retrofits of existing buildings, incorporation of renewable, green roof, and fuel switching including efficient equipment are mitigation measures (IPCC AR5th syr, 2014) that could improve building sustainability. Also, adaptive reuse is an effective building sustainability strategy; since it has been proven that it is cheaper to convert the building into another use than constructing a new building (Bullen, 2011).

Design guidance, environmental and energy assessments, and legislations have been used to improve the sustainability of buildings (Haapio and Viitaniemi, 2008). Particularly, building energy codes and performances assessment guidance are the most common policy tools for improving the EE of the existing buildings globally (Dascalaki et al., 2012). A past study (Kok and Jennen, 2012), based on two elements of sustainability (accessibility and energy efficiency), indicated that buildings with a lower EU EPCs rating (D or less), attracts almost 6.5% lower rent than those with the EPCs rating (A, B or C) in Netherland.

#### 2.4.6 Design Guidance, Energy Assessment and Legislation

The most significant regulation in the European Union (EU), is the energy performance of building directive (EPBD, 2002/91/EC). The directive aims at stimulating the enhancement of buildings energy efficiency and CO<sub>2</sub> emissions reduction in Europe, (Cotgrave and Riley, 2013). The UK's response to the EU directive cumulated in the establishment of the Climate Act 2008. The Act is the main legislative instrument that places stringent demand on energy performance of buildings.

### I. ENERGY REGULATIONS AND STANDARDS

#### *a. EU Energy Performance of Building Directive*

This is the energy efficiency and carbon reduction directive based on buildings' energy assessment across Europe. The directive informed the EU standard (CEN) PG-N37 (EU CEN EPBD, 2002), which directed member states to promote the improvement of energy efficiency

of buildings through the assessment and benchmarking of buildings (Appleby, 2013). It is also mandatory for energy assessment of all public buildings by accredited assessor and the issuance of energy performance certificates (EPCs) for display on buildings in Europe.

Tymkow et al (2013), explained that the EU EPBD imposes three legislative demands to stimulate CO<sub>2</sub> emissions reduction during building operational lifecycle. These are: Energy Performance Certificates (EPCs); Display Energy Certificates (DECs); and air-conditioning inspections. EPCs, are mandatory for new buildings, and must be produced when buildings are constructed, let out or sold by owners. Under the EPCs, building performance is graded on a scale of A to G as a ten-year valid certificate complemented by a recommendation report. This energy assessment must be carried out by an accredited assessor, and the builder bears the responsibility.

The DEC is mandatory for already occupied buildings on a regular energy assessment basis. It provides the overall picture of the energy consumption of existing buildings across Europe. Furthermore, the EPBD is the main policy mechanism on buildings' energy consumption in Europe as standard requires the following (Tymkow et al., 2013):

- ❖ Establishment of a common calculation methodology for assessing the energy performance of buildings
- ❖ Setting of minimum standards for building energy performance (new and existing buildings)
- ❖ Systems and procedures for energy certification of buildings (new and existing buildings), and
- ❖ Regular inspection/ assessment of installed boilers, air-conditioners and heating systems in buildings.

#### *b. UK's Climate Change Act 2008*

The UK's Climate Act 2008 set an aspiring Carbon reduction programme by requiring an 80 % reduction of CO<sub>2</sub> equivalent emissions based on 1990 base level by 2050, (Foxell, 2014). The programme proposed CO<sub>2</sub> emissions cut for both domestic buildings and non-domestic buildings. The targets for new domestic buildings are to be zero-carbon by 2016, and for non-domestic buildings are to be zero-carbon by 2019, (Cotgrave and Riley, 2013). The demand of the 80% CO<sub>2</sub> reduction targets by 2019 requires that all existing buildings (domestics and non-



domestics) must be of highly energy efficient with zero emissions status. Though this seems impossible, however, the UK has put in place a series of carbon capping schemes in order to achieve carbon neutral economy.

Several authors (Cotgrave and Riley, 2013; Tymkow et al., 2013; Foxell, 2014), have identified the following UK's carbon capping schemes: planning policy; building regulation (part L); and energy assessment tools (Standard Assessment Procedure for domestic buildings (SAP), and Simplified Building Energy Model (SBEM) for non-domestic buildings). Others are: Energy Performance Certificates (EPCs); Display Energy Certificates (DECs); and Incentives such as voluntary and non-voluntary means of energy assessment methods, and Enhanced Carbon Allowances (ECAs). The mandatory means of assessing BEP: are building regulations, Standard Assessment Procedure and Simplified Building Energy Model, which are statutory, non-voluntary means and compliance based. Whereas, the voluntary environmental assessment methodologies available in the UK are: CIBSE, BREEAM, etc.

### *c. UK's Building Regulations' Part L*

The Building Regulation is the statutory instrument that established minimum standards for the design and construction of new buildings and alterations to existing buildings. Part L: Conservation of Fuel and Power, in the regulation specifically dealt with the energy efficiency performance of buildings. The standard regulates the requirements and methodologies for producing EPCs and DECs required for the implementation of the EU standard (CEN) PG-N37 EPBD. The conservation of fuel and power section (Part L) is divided into four segments namely: part L1A for new domestic buildings; Part L1B (new non-domestic buildings); part L2A (existing domestic buildings); and part L2B (existing non-domestic buildings) (Cotgrave and Riley, 2013).

Since the 2002 edition, there have been several revisions made (2006, 2010, and 2013 versions and planned version in 2016) to the building regulation especially in the areas of fabric efficiency (thermal efficiency, stricter air tightness etc.) and installed services efficiency (Cotgrave and Riley, 2013; Tymkow et al., 2013). Foxell (2014), expounds that the 2010 version had a significant upgrade to part L aimed at achieving 40% lower CO<sub>2</sub> emissions than a building built in compliance to the 2002 regulations. The 2013 version required a further 6%



improvements on new homes and 9% improvement on non-domestic buildings on the 2010 levels.

*d. Simplified Building Energy Model and Standard Assessment Procedure*

These are Building regulation calculation methodologies with compliance calculating software. The compliance to part L of the building regulation, the Code for Sustainable Homes and data for EPCs, are dependent on the output from approved calculation software (Foxell, 2014). The Simplified Building Energy Modelling and its user interface iSBEM (version 4.1e, issued for Part L 2010 regulation) is the estimator for non-domestic buildings. The Standard Assessment Procedure is the main calculator for domestic buildings.

Standard Assessment Procedure is used to estimate the energy performance of domestic buildings. Whilst, Simplified Building Energy Model is the calculation machine used to check compliance with Part L for non-domestic buildings. It operates in conjunction with the National Calculation Methodology (NCM) using its interface software (iSBEM), its output module BRUKL for checking compliance, and EPC generator (Ibid).

*e. Energy Performance Certificates (EPCs)*

Several factors have been adduced for the EU's common energy policy on the buildings in extant literatures (Andaloro et al., 2010; Dascalaki et al., 2012). Firstly, the Building sector accounts for 40% of primary energy consumption and a third of CO<sub>2</sub> emissions in Europe. Secondly, 50% of EU's energy demand is imported dependent, and is envisioned to grow to 70% in the next 20-30 years. Thirdly, Climatic Scientists have predicted risk of earth's temperature rise by between 1.4 and 5.8°C; and if appropriate measures are not taken against GHGs emission that might cause further warming. Thus, a common energy policy, becomes extremely a critical factor for the European commission in reducing the impacts of this scenario.

The EU directive 2002/91/EC on energy performance of buildings (EPBD) was instituted as policy; and the use of energy certification of buildings became the core instrument for promoting the policy to monitor and reduce energy consumption in Europe (Andaloro et al., 2010). The EU directive 2002/91/EC on energy performance of buildings (EPBD) and the

EPBD recasts in 2010 and 2012 are the main legislative instruments for improving the energy efficiency of building stocks in Europe (Dascalaki et al., 2012).

The EPBD required all EU member states to enforce this directive by 2006 by entrenching national laws, regulations, and administrative provisions for setting up minimum requirements for the energy performance of new and existing buildings (with more than 1000 m<sup>2</sup>). Also, the regulatory requirements include amongst other (Pérez-Lombard et al., 2009; Dascalaki et al., 2012):

- ❖ Issuance of energy performance certificates (EPCs) in EU standard EN 15217, 2007;
- ❖ An assessment of the performance of existing buildings based on CEN standard EN 15603:
  - Calculated ratings (computer calculation based prediction) for predicting HVAC systems, domestic hot water and lighting energy use.
  - Measured (or operational) ratings based on the actual metering on-site

Pérez-Lombard et al., (2009), further expound that the calculated rating is classified into standard (asset) and tailored ratings. The asset rating is designed to rate the building not the users, and it uses standard calculation procedure independent of occupant behaviour, weather pattern and indoor conditions. It can be used during the design process, for new building (as built) or existing buildings. Whereas, tailored rating is used to tailor the actual condition (different usage pattern) prevalence at the time of assessment. It is used as benchmarking for existing buildings as recommended by CEN.

The EPC with its accompanying recommendation report is an asset rating. It informed potential buyers or occupiers on the intrinsic energy performance of a building and its installed services (Fuerst and McAllister, 2011).

These studies (Pérez-Lombard et al., 2009; Andaloro et al., 2010; Fuerst and McAllister, 2011; Dascalaki et al., 2012) emphasized the uses of EPC that:

- ❖ It gives understanding on the energy performance of existing buildings and helps enhances the performance of new buildings
- ❖ It is used as energy label as policy aimed to reduce CO<sub>2</sub> emissions from existing building stocks

- ❖ The EPCs expressed in index (energy consumption, CO<sub>2</sub> emissions or energy cost per unit floor area) are used to facilitate buildings comparison and benchmarking, etc.

Finally, Pérez-Lombard, et al. (2009) listed the content of EPCs as stipulated in European standard EN 15217 (B/540, 2007) as follows:

- ❖ An overall energy performance index (EPI) stated as in either energy consumption, CO<sub>2</sub> emissions or energy cost per unit of conditioned area for allowing for comparison between buildings
- ❖ An overall minimum efficiency requirement that is established by regulation as a limit of EPI (EPI<sub>max</sub>)
- ❖ A label based suitable grading in A-G bands including scale definitions, referring to at least: to the building energy regulations (RR); the existing building stock (R<sub>s</sub>); and the zero-energy building (R<sub>o</sub>), etc.

#### *f. UK's Display Energy Certificates (DECs)*

The EU directive 2002/91/EC on EPBD and standard EN 15217 (B/540, 2007), obligate that all buildings (at construction, newly built and existing) for occupation; sale or rent must have certificates indicating the rating of energy performances through the rating of CO<sub>2</sub> emissions. This certification is valid for ten years and must be renewed every ten years. Hence, in the UK, the certifications involve EPCs and the Display Energy Certificates (DECs) (Fuerst and McAllister, 2011). DECs were introduced in 2008 with the goal of improving public awareness of energy use, and to encourage and assist in the reduction, energy consumption and CO<sub>2</sub> emissions from building stock (Hawkins et al., 2012).

It is mandatory for public buildings to display a DEC that represent the actual energy used in the building (Koo and Hong, 2015). The rating is based on previous year energy consumption (a 12month interval); and a grading with letter A and G, with 'A' being the most efficient and 'G', being the least efficient. The grades are assigned numerical scores, which indicates the building's comparative efficiency (DECC, 2012).

The Chartered Institution of Building Services Engineers (CIBSE) (CIBSE, 2008), likewise, explicate further that DECs indicate a grading on an A to G scale based on the operational

rating; and that emissions benchmarking for a typical building category is based on actual energy used data. Benchmarking for a typical building category is based on actual energy used data. Also, DEC is obligatory for public buildings having more than 1000m<sup>2</sup> and must be displayed in a prominent and visible location of buildings at all time.

*g. CIBSE TM22 and TM46*

The CIBSE made the first publication of 'Energy Consumption Guide 19 (Energy use in Offices) in 1995 and reprinted in 2000'. This was accompanied by 'Good Practice Guidance on Energy Efficiency in Buildings' in 1997. CIBSE TM22, TM46 and TM39 were specifically focused on the non-domestic building sector in the UK (CIBSE, 2008).

CIBSE TM22 is an assessment procedure for the energy performance of an existing building centred on metered energy used and methodology for software application. It is an energy monitory and management tool for energy assessors, building managers and facilities managers (CIBSE, 2006b). The CIBSE TM22 (2006), key features are as follows:

- ❖ Main assessment procedure options that comprises of: option A for simple building assessment; option B for General building assessment; option C for System assessment; and others category.
- ❖ Declaration of the purpose for assessment (either for legislative requirement or information),
- ❖ Use of the TM22 software application, and
- ❖ Appendixes: A1-A8 Glossaries.

Whilst, CIBSE TM46 is the UK's statutory operational rating and benchmarking procedures established to implement the energy performance regulation (DECs). TM46 procedures contain the following (CIBSE, 2008):

- ❖ 29 benchmark categories, each representing a functional group for benchmarking individual building against the group
- ❖ Benchmark values expressed in delivered energy use per unit of floor area (fuel and fossil fuel energy consumption), and converted into CO<sub>2</sub> emissions per unit area (kgCO<sub>2</sub>/m<sup>2</sup>) for the operational rating purpose

- ❖ Measurement procedure for annual consumption periods (measured over 365days), separable energy uses, adjustment to benchmarks (weather and occupancy adjustment), and criteria for mixed use buildings
- ❖ Description of the benchmark table; and
- ❖ Appendixes on definitions and explanations for the following: A1- weather adjustment; A2- separable energy use; A3- occupancy adjustment; and A4- notes on specific building types.

TM46 have 237 building types defined under these 29 categories, and buildings that have activities that span more than one category are labelled a ‘composite benchmark’ relevant to the building (Hawkins et al., 2012). Furthermore, the CIBSE TM46 is used for DEC’s system where TM46 classification is based on rationalised and simplified values from the various sources. TM46 system has separate benchmarks for electrical and heating fuel with criteria for adjustments for occupancy (total annual occupied hours) and weather (degree day) (Bruhns et al., 2011; Hawkins et al., 2012).

#### *h. US’s ASHRAE STANDARD 90.1*

The American Society of Heating, Refrigerating and Air-Conditioning (ASHRAE) Standard 90.1 is an energy code and standard for buildings (excluding low-rise buildings) used in the USA. It follows the International Energy Conservation Code. Also, ASHRAE 90.1 is the minimum energy efficiency standard required for non-domestic buildings and domestic buildings not more than three heights in the USA (Aspenpublisher, 2011). ASHRAE (ASHRAE, 2015), made her first in-house original standard 90.1 in 1975. It was revised with subsequent editions in 1980, 1989, and 1999, using the American National Standards Institute (ANSI) and ASHRAE periodic maintenance procedure.

ASHRAE 189.1 punished in 2010 in conjunction with the Green Building Council and the Illuminating Engineering Society, was formulated to complement the requirements established by ASHRAE 90.1 and other Codes such as LEED. ASHRAE 189.1 covers such areas as: site sustainability, water efficiency, indoor environmental quality, material and resources, including definition of scope, obligatory requirements, compliance, performance options and prescriptive options (Aspenpublisher, 2011).

Several authors (Aspenpublisher, 2011; Boldt, 2014; Ehrlich, 2014), confirmed that ASHRAE complete her debut as recognised standard with first publication of ASHRAE 90.1-2004 (in 2004). It was revised with consequent editions such as: ASHRAE 90.1-2007 (in 2007), ASHRAE 90.1-2010 (in 2010), and currently with ASHRAE 90.1-2013 (in 2013). These authors argued that since the 2004 editions, successive ASHRAE updates were designed to achieve 30% energy savings based on ASHRAE 90.1-2004 as base year.

Consequently, a total of 153 supplements with estimated 28 of these embedding energies saving benefits have been made in areas such as: normative, lighting controls, opaque and fenestration envelope requirements, solar heat gain calculation adjusted for projection factors and updated ventilation rate based on ASHRAE 90.1-2004 (Aspenpublisher, 2011).

## II. NON-REGULATORY AND VOLUNTARY STANDARDS

The non-regulatory standards are voluntary means of assessment, which are mainly environmental assessment tools that enable sustainable credentials of buildings to be measured (Cotgrave and Riley, 2013). These tools encompass wider environmental sustainability criteria (ecology, water, waste, pollution, management, flood, indoor air quality, etc.) including energy and CO<sub>2</sub> emissions from buildings. Though they are voluntary means of assessment methodologies, but are mostly used by clients in giving briefs to designers and contractors.

In the UK, BREEAM is available, while in other developed countries, we have PassivHaus standard, LEED, NABER, CASBEE, etc., as illustrated (Appendixes 2A-C). Furthermore, there are emergence of building councils worldwide that champions the course of building environmental sustainability. Amongst these are the UK Green Building Council, US Green Building Council (USGBC), and the Green Council of Australia etc.

### *a. Global Green Councils*

The World Green Building Council (WGBC) is a non-governmental organisation (NGO) located in Toronto, Canada. It is a network of national green building councils in more than 100 countries influencing the green building marketplace globally. Its membership is categorised into three levels, namely: prospective, emerging and established members (WorldGBC, 2015).

Some of the identified leading GBCs with respective operating environmental assessment methods for rating and certifying systems around the world are: The UK GBC operates the UK's BREEAM, the US GBC operating LEED, the German GBC operating DGNB system, the Australia GBC operating Green Star, the Canadian GBC (iiSBE) operating SBtool, and the Japanese JaGBC operating CASBEE etc.

It's worthwhile to mention that South Africa GBC hosted the World Congress of the WGBC in Cape Town in 2013 and the majority of the established African GBCs (Namibia, Kenya, Mauritius, Sudan, Tunisia, Zambia and Ghana) are in the emerging membership category of WGBC except for South Africa GBC (Sedlacek and Maier, 2012; WorldGBC, 2015).

WGBC's global environmental governance movement is now recognised as a vibrant market-driven governance system. The WGBC is an NGO building global network that enables the setting up of green councils worldwide. Also, the role of its regional green building councils (RGBCs) has grown in their governance and third-party role, (Sedlacek, 2014).

The IPCC, (2007) and Sedlacek (2014), also confirmed that the green building sector grew very fast in the last decade and became exceptionally dynamic regarding its institutional formation, public awareness and its share in the built environment. This is because building has been identified as the largest energy consumer among the three-major energy consuming sectors (building, industry and transportation).

Earlier study (Sedlacek and Maier, 2012), identified the functions of Green Building Councils (GBCs) worldwide as: promoting the sustainable construction and building awareness of sustainability issues; lobbying for the entrenchment of building codes and building sustainability policies, and the issues of sustainable development generally; and identification of best practices through the application of sustainable building rating system.

#### 2.4.7 Government Policy Measures and Incentives

Several barriers prevent the full uptake of energy saving measures. Policy measures as external stimuli towards low carbon buildings are needed for correcting market failure, and encouraging new businesses and financial models that overcome the first-investment cost hurdle (Lucon et al., 2014). Policies have been focused on technological improvement in energy efficiency, and

consumer behavioural and lifestyle changes based on concept of self-sufficiency. These strong policies are also being used in achieving drastic reduction in BEU in recent years especially in developed countries.

Policy dynamism and its enforcement are crucial to BEP. The IPCC 5<sup>th</sup> AR explained that constant revision by incorporating technical and market changes, and regular strengthening of policy with follow-up enforcement have helped to achieve the full potential of policy measures. It further classified policy title and brief definition into five categories (Lucon et al., 2014):

### *I. Regulatory Measures*

Building codes and appliance standards (Minimum Energy Performance Standards- MEPS) are the most widely used cost-effective instruments globally. Building codes are sets of standards for buildings or building systems, determining minimum requirements of energy performance; while appliance standards (MEPS) are the rules or guidelines for a equipment class and set a minimum efficiency level that ban the sale of any underperforming equipment (Lucon et al., 2014).

### *II. Information Instruments*

These are equipment's energy labels, building labels and certificates, and mandatory energy audit. They are also cost-effective instruments that can be used to support regulatory measures or that can be as stand-alone with effective enforcement measures.

Energy labels are either mandatory or voluntary declaration of information about the energy / other resource use of end-Products at the point of sales. Building labels and certificates are building ratings based on their energy performance and should provide credible information to users/ potential buyers. Building labels could be mandatory such as the BEU energy label or voluntary such as BREEAM, European Green Building label, Minergie, LEED, NABER, PassivHaus etc. There is increasing use of labels which are already influencing market prices worldwide (Brounen and Kok, 2011; Lucon et al., 2014).

Mandatory energy audits are mandatory examination and calculation of energy performance of existing buildings to identify cost-effective potentials. Lucon et al (2014), suggested that audits should be mandatory and subsidised particularly for developing countries. They should be



reinforced by incentives or regulations that need the implementation of cost-effective measures.

### *III. Direct Market Intervention Instruments*

They include sustainable public procurement and promotion of energy services. Sustainable public procurement is often practiced by public sector bodies using pre-set procurement regulations based on energy performance and sustainability standards. It involves setting high standards of energy efficiency criteria for all products that the public buys. Also, promotion of energy service schemes such as energy performance contracting (EPC) delivered through ESCOs, often aims to increase market and quality of energy services, offers, (Marino et al., 2011; Lucon et al., 2014).

### *IV. Economic Instruments*

Lucon et al. (2014), classified economic instruments as Energy Efficiency Obligations and White Certificates, Carbon Markets, Energy and Carbon Tax, Taxation tool, Grant and Subsidies, and Soft Loans (including preferential mortgages). Energy efficiency obligation set, record and show that specific amount of energy has been saved with the incorporation of trading. Carbon markets set up trading and distribution permits for excess carbon emissions from the total number of allowable limits.

They do provide tradable permits as market-based instruments. Other economic instruments include: energy and carbon tax levied on fossil fuels or energy using products based on product's energy demand and carbon emission content; soft loans for carbon reduction measures with low interest rates; grants and subsidies as incentives for investment in energy efficiency projects (example, for building renovation in Poland, Estonia and Hungary); and the use of taxation in form of reduces VAT, accelerated depreciation, tax rebates, tax deduction etc.

### *V. Voluntary Agreements*

These are voluntary and negotiated agreements, awareness raising and information campaigns, individual feedback mechanism, and public leadership programmes. Voluntary and negotiated agreements are binding agreements between private housing associations, or facilities owners on limits of emissions on energy efficiency targets with government. These targeted objectives

become binding agreement between them and government. Awareness and information campaigns are tailored towards influencing behavioural change to more effective energy use behaviour. It also helps to stimulate awareness on the adoption and use of more energy efficient technologies. These are in the form of green consciousness and conservationist movements, increasing global climate change and sustainability awareness, adoption of smart meters with direct feedback mechanism etc. (Lucon et al., 2014).

#### 2.4.8 UK Government's Action on Improving Building Sustainability

The UK's government developed and launched a series of measures to meet its targets for reducing GHGs emission under the Kyoto Protocol; and assist the EU to achieve its target (Environment and Energy, 2000). Some of these are: Government Energy Action, Government's Enhanced Carbon Allowance Scheme (ECAS), and Foundation Programme, etc., are expounded in the current study (Appendixes 3A-C). These actions yielded good results as shown in previous UK Government reports in 2002 (Vincent, 2003), that companies in the Climate Change agreement had achieved 13.5 million tonnes cut in CO<sub>2</sub> emissions. This was about three times above their collective targets and it shows that a voluntary agreement is feasible and could be very effective.

## 2.5 ENERGY IN BUILDINGS

### 2.5.1 Energy Consumption and CO<sub>2</sub> Emissions in Buildings

The energy we use in our buildings can be categorised as total, delivered, or end-use energy. Delivered or end-use energy is the energy content of primary energy delivered to the consumer at the degree of end-use. Likewise, the total energy used in the building is the total of all delivered energy to the building boundary by each carrier (Ward, 2004; Levine et al., 2013).

The actual energy used should be converted into equivalent carrier based on three main conversion methods, namely; calorific value, primary energy and electricity equivalent approaches. In assessing and benchmark of energy performance, it is necessary to apply energy conversion factors based on calorific value or primary energy approach of energy sources (Levine et al., 2013).

Levine et al., (2013), explained that the calorific value approach is based on the heat stored in an energy carrier and it's useful for on-site energy. The primary energy traced the original heat source of the primary energy. It is only useful for electricity conversion of primary energy via conversion coefficient for that amount of energy used. Thus, other primary energy sources: gas, coal, kerosene, fuel and diesel do not need conversion; in these, caloric value and primary energy approaches are the same.

Energy used in buildings has been associated with GHGs especially CO<sub>2</sub> emissions. In 2010 alone building consumed 117 Exajoules of global energy used, which is about 8.8 Giga tons of CO<sub>2</sub> emission after conversion (Lucon et al., 2014; Taboada, 2015). The CO<sub>2</sub> emission quantity is derived from the application of either; the caloric value or primary energy approach of each energy source of a country. To get the capacity of different energy sources to do the work it is useful to the electricity equivalent approach. It implies that; as world energy consumption increases, there is a corresponding increase in CO<sub>2</sub> and other GHGs emission (Levine et al., 2013).

For example, world energy consumption rose from 14% in 2005 to 27% in 2014; and it estimated energy-related CO<sub>2</sub> emissions are projected to increase to 36.7Gt in 2040, about 16% > than in 2013 (OECD/IEA, 2015b).

The delivered energy is for powering our lighting, cooling, heating, hot water, cold water, cooking, electronics and other equipment in the buildings (Ward, 2004). In 2010, the building sector accounts for 32% of final global energy used and 8.8 Giga tons of CO<sub>2</sub> emissions (Taboada, 2015). The regulation of BEU worldwide is aimed at reducing GHGs emissions, as building stock has enormous potential for energy conservation and efficiency. Hence, the regulation of BEU through building codes and another voluntary instrument are accepted, and proven to be an effective strategy globally.

### 2.5.2 Energy Conservation and Energy Efficiency

The concepts of energy conservation (EC) and energy efficiency (EE) are distinctly different in meaning. Nevertheless, both are being used interchangeably in extant literatures. Several studies have explicated on the origin and meaning of both concepts (Patterson, 1996; Moezzi, 1998; Herring, 2006). The most distinct definitions for both is the one advanced by Moezzi

(1998). He opined that EC is doing a work without energy use to save energy or money; whilst EE is getting the most from every kWh of electricity purchased.

He further stressed that while, EC is focused on how the quantity of energy used; EE focused on how much quantity of energy used in relation to the services provided. He also cautioned that EE may not result in conservation as it might contribute to the tendency to waste more. Whilst, Herring (2006) upheld conservation and stressed that “efficiency tells us what to buy, conservation tells us how to behave”

Other authors (Patterson, 1996; Herring, 2006) expounds that EE is the ratio of energy services output to the energy input. Patterson (1996) exposed further that EE is generic in meaning and it cannot be measured. The only exception is the change in EE that can be measured through a set of indicators. He listed the indicators as: thermodynamic that relies on science of thermodynamics; physical-thermodynamic that relies on hybrid indicator with input via thermodynamic and output via physical units; economically-thermodynamic that relies on hybrid indicators where service delivery (output) is measured in unit of market prices; and the economic indicators that measure change in EE purely in market value.

Moezzi (1998), however, acknowledged that the concept of EE is more of a subjective rather than absolute concept, since it has a narrow application that focuses on the technological EE of energy use and overlooks user behaviour that also drives energy consumption. Whilst, Herring (2006), argued against the promotion of EE; insisting that EE will not always lead to energy saving and reduction in CO<sub>2</sub> emissions. He claimed that the ‘take-back’ or ‘rebound’ effect will come into play; and in that savings from EE improvement might take the form of higher energy usage.

Energy is considered as the most conserved resources; and its conservation could be achieved through switching-off habit or through loading shedding in generator usage (Adewunmi, Omirin and Koleoso, 2012). EE is when energy consumption devices, such as electrical appliances or an elevator uses less energy while providing the same level of service for a building (e.g., cooling, lighting, motor drive). Efficiency improves when the device undergoes a technical modification, or using certain design changes such as better insulation, thermal windows, improved ventilation, and solar orientation. The energy-saving result of an efficiency increase is referred to as ‘energy conservation’ (Parfomak, Sissine and Fischer, 2009).

EE is the quickest, most effective and cost-effective ways of reducing emission of GHGs and improving indoor and outdoor air quality. Also, is the most relevant tool for reaching non-reliance on imported fossil fuel; and mitigate against climate change risks (Chai and Yeo, 2012).

The practice of EE and EC is proven to offer significant mitigation against supply challenges (Sambo, 2008). Thus, improving the energy efficiency in an existing building has become a central goal of the global sustainability agenda (Juan, Gao and Wang, 2010). A recent study (Lu, Zheng and Kong, 2016), validates its adoption for the current study. It found that a decrease in the electricity use percentage of an office building and increase in the use of wind or natural gas or solar energy, improved the energy efficiency of government office buildings in China.

### 2.5.3 Concept of Thermal Comfort and IAQ

The physiological mechanisms of our bodies rule our thermal comfort. Body physiology varies from person to person; therefore, we can have different level of comfort or discomfort in any specific thermal condition (Randall, 2012). Also, the human body is a thermodynamic machine, it exchanges heat to and from the environment through the thermodynamic process of conduction, convection and radiation. The conducted heat gains or losses are governed by our clothing, the removal of sweat, and to some extent heat by convection (air movement); and further heat gains or losses by thermal radiation to the environment (Ward, 2004).

Various studies (Ole Fanger and Toftum, 2002; Randall, 2012), have established that the total quantity of heat in our body and transferred into our environment from the body depend the person's age, sex, size, activity and clothing. While, personal variables (activity, historic period, gender and clothing) and physical variables (air temperature, air motion, surface temperatures and humidity), are the underlying factors that affects thermal comfort.

Fanger and Toftum (2002), opined that thermal sensation is closely associated to the thermal load on the effect of the mechanisms of the human thermoregulatory system. They used the PMV (predicted mean vote) model to predict the thermal sensation as a function of occupant's

personal variables and room physical variables in both HVAC and non-air conditioned environment in warm climates.

### *I. Activity and Metabolic Rate*

The greater the activity of an individual the more heat his or her body emits (Randall, 2012). Ward (2004), explains that the metabolic rate and clothing levels have significant impacts on sensation of thermal comfort. The quantity of energy released is converted to heat in the body, which depends on the amount of muscular activity. Randall (2012) measured activity by the rate of heat emission, which depends upon the surface area of a person and the person metabolic rate.

### *II. Clothing and Clo-value*

Clothing is a thermal insulator that helps to maintain the skin at a comfortable temperature, (Randall, 2012). It reduces the body heat loss thereby insulating the body, (Ward, 2004). Clothing insulation is called clo-unit or clo-value, and  $1 \text{ clo} = 0.155 \text{ m}^2 \text{K/W}$  of insulation with values from 0 clo to 4 clo. Also, study (Ole Fanger, 2001), indicates that clothing kept the thermal sensation of a subject's body neutral without modification to the subject's clothing.

### *III. Air Velocity*

The movement of air over the human body helps remove heat by convection. The faster the movement of air over our bodies the more its ability to remove heat by convection is increased. The general acceptable range of air velocity for comfort is 1.0 - 1.5 m/s (Ward, 2004; Randall, 2012). However, air movement rate differs from air change rate, and is not always caused by ventilation; and air movement greater than 0.1 m/s in speed will need higher temperature to meet the same level of comfort (Randall, 2012).

### *IV. Air Humidity*

The earth atmosphere contains air with 5% water as the total mass of gases contained in the air. This condition of moisture or humidity is contained in the form of water vapour. Hence, humidity is the degree of wetness of the volume of air within a space (Randall, 2012). The acceptable percentage of humidity for comfort is within the range of 70% to 80%, (Ward, 2004). Previous study (Toftum, Jørgensen and Fanger, 1998), has established that skin humidity could cause discomfort; and as such a function of environmental parameter, clothing characteristic and activity.

#### *V. Air and Mean Radiant Temperature*

There is often the difference between the air temperature and the surface temperature of floor, walls, window and ceiling within space in a building indoor environment. The difference between the mean radiant temperature and the air temperature can result in a person feeling either too hot or too cool. The mean radiant temperature is usually used to understand the concept of occupant perception of comfort about indoor air temperature (Ward, 2004; Randall, 2012).

#### *VI. IAQ*

Past study (Ole Fanger, 2006), also, has shown that the indoor air quality (IAQ) in a building has effects on employee productivity in the workplace. Fanger asserts that the occupants' air requirement for an indoor environment is that the air should be: fresh and pleasant; odour free and no negative impact on their health; increase their productivity and student learning in school. The IAQ extend is to which these requirements are met. His study proved that improving IAQ by a factor of 2-7 compared to present practice and standards decreases risk of allergy/ asthmas, increases productivity in the office and improve learning in schools.

Fanger, further suggested five principles that underpinned thermal comfort and IAQ as excellent panacea for EE and building sustainability, which are: better IAQ increases productivity and decreases sick building syndrome (SBS) symptoms; avoidance of sources of indoor air pollution; availability of cooled and dry air; provision of personalised air to occupant's close to the breathing zones; and individual access to the thermal control (Ole Fanger, 2001).

#### **2.5.4 Ergonomics of the Thermal Comfort**

The ergonomics of the thermal comfort is an analytical determination and interpretation of thermal comfort using the PMV and PPD (predicted percentage of dissatisfied) indices and local thermal comfort based on ISO 7730: 2005. BS EN ISO 7730: 2005, present methods for predicting the general thermal sensation and the degree of discomfort (dissatisfaction) of people exposed to moderate thermal environment condition (ISO, 2017; Fanger, 1970; Olesen and Parson 2002).

ISO 7730: 2005 enable the determination and interpretation of thermal comfort using calculation of PMV and PPD and local thermal comfort, giving the environmental conditions considered acceptable for general thermal comfort as well as those representing local discomfort (ISO, 2017). Its scope is also applicable: to draught rating (DR), which is the percentage of people dissatisfied due to draught; healthy men and women exposed to indoor environment where thermal comfort is desirable; and differences in ethnic, national or geographical locations must be considered when measuring non-conditioned spaces (Olusen and Parson 2002).

The standard set specifications for comfort based on technical regulations that allow its assessment based on a substantial objective basis. Lenzuni, Freda and Del Gaudio (2009), expound that the standard made classification a compulsory precondition for thermal assessment based on category of specific work situation being investigated as appropriate criteria. They expound that for over 25 years, thermal comfort for any environment can be express in either the PMV ( $-0.5 \leq PMV \leq +0.5$ ) or the PPD ( $\leq 10\%$ ) as the single criterion for acceptable global thermal comfort in ISO 7730: 1984). But the PMV single criterion has been replaced by three different special working situations (SWS) in the form of:  $-x_j \leq PMV \leq +x_j$ , (ISO 7730: 2005), where  $x_j$  represent the different values ( $x_A = 0.2$ ;  $x_B = 0.5$  and  $x_C = 0.7$ ) under separate contexts; and has been delegated to national or local regulations to categorize.

Human response to the six fundamental comfort factors of air temperature, radiant temperature, air velocity, humidity, clothing and activity determine the thermal comfort of an environment. Extant literatures (Olusen and Parson 2002; Lenzuni, Freda and Del Gaudio, 2009; Fanger, 2001; Fanger, 1970), expound on how a combination of these factors could be predicted using the index of PMV or PPD. The index of PMV could predict the mean value of the votes of a large group of persons based on the heat balance of the human body using the 7-point thermal sensation scale: +3 (hot), +2 (warm), +1 (slightly warm), 0 (neutral), -3 (slightly cooler), -2 (cool), and -1 (cold). Whilst, PPD is an index that predicts the percentage of thermally dissatisfied people, which is the percentage of a large group of people who will vote: +3 (hot), +2 (warm), +1 (slightly warm), 0 (neutral), -3 (slightly cool), -2 (cool), -1 (cold) on seven-point thermal sensation scale.



The ISO has separate specifications for assessing other special thermal comforts for special environments such as: ISO 14415 (for people with special needs); ISO 14505 (thermal comfort for vehicle); and ISO 13732 (responses on contact with surfaces at moderate temperature). Standards that support thermal comfort assessment include: ISO 7726 (measuring instruments); ISO 9920 (estimation of clothing properties); ISO 8996 (estimate of metabolic rate heat production); and ISO 10551 general method of thermal comfort for subjective measurement. Whilst, ISO 10551: Subjective scales are based on: Perceptual (how do you feel now e.g., hot or cold?); Affective evaluation (how do you find it e.g. comfortable); Preference (how do you prefer it, cold or hot?); Personal acceptability (is the environmentally acceptable?); and Personal tolerance (is the environment tolerable?) (Olusen and Parson 2002).

#### 2.5.5 Adaptive Comfort

Comfort adaptation is a human's gradual adjustment to repeated environmental stimulation in the form of: behaviour (clothing, window, and ventilation), physiological (acclimatization), and psychological (expectation) (Halawa and van Hoof, 2012). The adaptive comfort model is underpinned by the existence of occupant's personalised control to natural ventilation and access to the thermal control (Ole Fanger, 2001). Fanger's adaptive comfort model predict the thermal sensation of non-air-conditioned buildings in warm climate based on variations on external temperature. Nevertheless, it does not consider human clothing or natural action and other four thermal parameters (air temperature, mean radiant temperature, air speed and humidity) that impact on the human heat balance (Ole Fanger and Toftum, 2002).

Halawa and van Hoof (2012), affirm that in adaptive comfort approach, the responsibility of obtaining thermal comfort, lies with the occupiers with a proportional degree of command over his or her thermal environment. Adaptive approach reflects the thermal sensation of occupants better than the PMV (predicted mean vote) / PPD (predicted percentage dissatisfied) model in naturally ventilated buildings. However, the PMV predicts the thermal sensation well in buildings with HVAC systems globally; and is based on the absolute and perceived thermal sensation as a function of the activity, clothing, and thermal parameters (Ole Fanger and Toftum, 2002).

A past study (Barlow and Fiala, 2007), on occupant comfort in UK office based on the use of eight surveys, indicated that the majority voted for controlling: window opening (74%), solar

glare (69), and solar gain (47%), local control of lighting switch (56%), opportunity to increase levels of ventilation (55%) and localized intervening for altering room temperature (50%) as adaptive thermal opportunities. Thus, the study suggested that future office refurbishment should consider them as active adaptation measures as refurbishment strategies to improve occupants' comfort including reducing BEU and CO<sub>2</sub> emissions.

#### 2.5.6 Factors that affect Energy Consumption and CO<sub>2</sub> Emissions in Buildings

A BEP is dependent on intrinsic factors that determine its energy use; which are well established in past studies (Ole Fanger, 2006; Li, Hong and Yan, 2014a). These factors: building envelope, building HVAC equipment, climate zone, operation & maintenance, occupant behaviour, indoor environment condition and building size, is fundamentally built upon BEE and carbon emission reduction as determinants (Ward, 2004).

A past study (Li, Hong and Yan, 2014a), proved that there is an association between building energy use intensity (BEUI) and floor areas; and that large building consumes more energy than smaller ones. However, as the building size increases, their BEUIs decreases. It indicates that building size along with climate or technology are not decisive factors. It also revealed that occupant density and operation hours are deemed to cause substantial effects on BEU. Although, no single factor influences BEU, nevertheless, occupant behaviour, and operation & maintenance play major roles in energy saving potentials of office buildings.

Buildings' fabric deteriorates as they get older, and installed equipment efficiency decreases too. Hence, operations and maintenance plays a critical part in energy saving schemes, and a crucial factor influencing BEU. Maintenance and refurbishments are very useful for improving the energy efficiency of a building. Maintenance and refurbishment is the work undertaken to keep, restore or improve every facility, its services and sounds to a currently accepted standard in sustaining the utility and value of the facility (Jones and Sharp, 2007).

Lucon et al. (2014), also, alluded to behaviour, lifestyle, and culture as major factors influencing BEU. They argued that in developed countries, behaviour influenced by awareness of energy and climate issues can reduced demand up to 20% in the shorter; and 50% of present levels by 2050.

BEU can be driven by other factors like operation hours, numbers of occupants and building functions. Building envelope design and insulation can help leverage the benefits of heat loss/heat gain, natural ventilation and Daylighting reduce the use of mechanical cooling and artificial lighting during building operation. They are major contributors to BEU and BEE, hence equipment efficiency is very important for energy saving (Li, Hong and Yan, 2014a).

Studies (Ma et al., 2012; Agha-Hosseini et al., 2013), have shown that energy retrofits and installation of electrical and mechanical technologies such as efficient lighting systems and envelope, heating, ventilation, and air-conditioning (HVAC), have helped saved energy in existing buildings; and are crucial factors that determined their BEP. The Climate Action Report also confirmed that, ‘by commercially available energy efficient products, technologies, and best practices, many commercial buildings and homes could save up to 30 percent on energy bills’ (Parfomak, Sissine and Fischer, 2009).

Climate is another critical factor that affects BEP. A simulation thermal analysis study (Shibuya and Croxford, 2016), indicated that the total BEU for cooling and heating in office buildings in three Japanese climate regions will increase in global warming at different rate dependent on location. Its validate climate zone as a determinant of BEP.

## 2.6 BARRIERS AND DRIVERS TO BUILDING ENERGY PERFORMANCE

### 2.6.1 Barriers

The Lock-in report 2007: “Carbon lock-in: Barriers to deploying climate change mitigation technologies” (Parfomak, Sissine and Fischer, 2009), identified barriers to energy end-use efficiency in buildings. The report classified barriers as: critical barriers (industry structure, incomplete/ imperfect information, technical risks, market risks, unfavourable fiscal policy, etc.); important barriers (external benefits and cost, lack of specialised knowledge, policy uncertainty etc.); and other barriers (infrastructure).

The structure of construction and allied industries is complex. Hence, the decision-making, relationships between various professionals and other stakeholders within the industry is complex and fragmented, which is a critical barrier to building energy efficiency. Another barrier in the report is the situation of incomplete and imperfect information on availability of

efficient technologies and cost-effectiveness of efficient solutions. The lack of information and lack of confidence by the consumers, and prohibitive cost transition for obtaining information are cited. High initial cost of implementing energy efficient programme in buildings also hinders its uptake. While unfavourable fiscal policies in the form of rate structure of utility bill were identified as a barrier (Ibid).

Lucon et al, (Lucon et al., 2014), reported imperfect information, split incentive, lack of awareness, transaction costs, inadequate service levels, subsidised energy prices, and high discount rates as additional key barriers to building energy efficiency. Other barriers identified by them are: lack of access to financing, principal agent problem, fragmented market and institutional structure, poor feedback and enforcement of regulations, risk aversion, cognitive and behavioural patterns, and poor personal qualification.

#### 2.6.2 Drivers

The drivers of BEP are also well documented in these reports (Parfomak, Sissine and Fischer, 2009; Lucon et al., 2014). Policy intervention at building lifecycle phases, appliance life span and use; including new business and financial models are useful tools for driving BEE. Also identified are: carbon tax; extension of feed in-tariffs to smaller capacity; and soft loan given in favour of renewable energy purchases; tax exemption and appliance standards for EE of technology; building codes; preferential loans; subsidised financing schemes; EPC; etc.; and awareness raising, education, energy audit, building energy labelling, and energy or carbon tax are listed drivers.

Remarkably, evidence (IPCC 4TH AR), demonstrated that the EE programme in buildings recorded 25-30% energy efficiency improvement being available at a cost significantly lower than normal supply. Policy dynamics and development in BEP have made total building energy use to start decreasing. Building codes and appliance standards with strong EE requirements (that are well tightened, enforced, adapted to local conditions and environment) are judged to be the most environmentally and cost effective. Specifically, technology and architecture, behaviour, lifestyle, and culture have shown 3-4-fold difference in BEU reduction (Lucon et al., 2014).

The IPCC 2014 reported that evidence indicates that behaviour informed by awareness of energy and climate issues can reduce demand by up to 20% and 50% in the short and long term respectively. The IPCC 2014 report confirmed earlier claims by the US Department of State's 2006 Climate Action Report, which asserted that 'by commercially available energy efficient Product technologies, and best practices, many commercial buildings and homes could save up to 30 percent on energy bills'.

### 2.6.3 Peculiarity of Nigeria BEU

Energy used in buildings in Africa is estimated at 56% of the total national electricity consumption. Its demand increases annually by 8% against short supply, which led to gaps in the continent's supply, demand chain, (Kitio, 2013). Available data indicate that Nigeria operating capacity for all electricity generating companies, currently is decreasing from recorded data by 3,149MW (2007), 5,516MW (2012) (E.C.N., 2013), to below 4,000MW presently.

Nigeria energy generation capacity is over stretched by rapid population growth, increasing standard of living, urbanisation, growing industries and climate change (Sambo, 2007; World Bank, 2013). This is primarily due to obsolete and disrepair electricity generating plants. The scenario has created a vast shortage in supply-demand chain, contributing to emergence of generators' use. The energy supply-demand shortfall is supplemented with diesel-powered and fuel power generators despite inherent potential environmental implications. Consequently, about 12-13million litres of fuel are being consumed daily by generators to supplement the shortage of electricity supply within the commercial, industrial and domestic sectors (Abbas, 2012.).

The incidence of frequent blackout of about 35times power outage per month (E.C.N., 2013), lack of policy framework and regulation for BEP, and absence of building energy codes for operational and technical frameworks, are also associated barriers that confront BEP. Furthermore, legislations on energy performance standards are used to drive EE in Europe and other developed countries, (EU Directive, 2002). This can be adopted in the Nigeria case to drive office BEP. Appropriate policy guideline, standards and labels are commonly used driver for promoting EE. It is a common norm to see labels and standards specification on electric appliances worldwide (GEF-UNDP, 2011).

Increasing the awareness of energy efficiency and climate change is another driver for reducing commercial buildings' energy use. Public awareness of climate change has proven to stimulate organisations to consider strategies for reducing energy consumption both for economic and environmental reasons (Schelly et al., 2011).

FM services can be used to drive down office BEU. The FM should develop key competence skills in sustainability issues, reviewing and monitoring of facility energy use, and adopting EE measures (IFMA, 2007), this could be harnessed to improve BEP in Nigeria. Past studies (Elmualim et al., 2010; Tanneja, 2014), identified energy management, renewable energy technology, market forces, and BEM technology as drivers for BEP. There is now shifting toward integration of smart building technologies, training of operations and maintenance staff into all aspects of design, construction and operations of buildings (Tanneja, 2014). These offer credible potential for the office buildings in Nigeria.

Economic and fiscal incentives, soft loans (maximum of 5% interest rate), and subsidies for energy efficient equipment (up to 30% initial capital cost), likewise, have been identified as drivers for reducing energy consumption in Nigeria (Sambo, 2007). The government can adopt some of these policies to encourage BEU reduction.

## 2.7 IMPROVING BUILDING ENERGY PERFORMANCE (BEP)

### 2.7.1 Technical and Operational Interventions

#### *1. Technologies for Managing BEU*

The advent of sustainability and EE ushered in technological innovations in building energy management (BEM). It led to increasing research focus on green technology for BEM, and environmental friendly smart grid. Correspondingly, it led to a shift in public and private sectors' strategic direction and perception of smart building technologies (Tanneja, 2014).

The adoption of installation of intelligent building's technology as BEE intervention is now the norm worldwide. It is now deemed a 'best practice' for a building to be installed with lighting system sensors, smart meters, building automation systems (BAS) and data acquisition

system (DAS) as a mark of high BEP. Such equipment is utilized for monitoring, tracking, benchmarking and self-diagnostic for energy consumption management (Lucon et al., 2014).

BEMS are technologies deployed to help monitor and control installed HVAC equipment in modern buildings. Computer-based remote control and continuous monitoring of energy usage via control systems for: heating, air conditioning, lighting and transportation, delivers a higher level of efficient performance of HVAC equipment than that which can be achieved manually. BEMS comprise of a supervisor computer that is networked to microprocessor outstations. The complete network comprises of the programmable logic controller and energy management system (EMS). The logic controller is a dedicated microprocessor that is used for operating certain plant item in a building. It can be programmed to operate passenger lift, boiler or refrigeration compressor etc. (Chadderton, 2013).

Past studies (Dounis and Caraiscos, 2009; Agha-Hosseini et al., 2013), indicates that these interventions have been successful. Particularly, the use of advanced control systems has been shown to achieve a higher comfort level and result in energy savings in buildings. Whilst, BMS and sensor systems have aided energy reduction in office buildings via reducing employee control over energy usage in the workplace.

Building management system (BMS), is the use of technologies to manage the combination of all the functions carried out by the building. Smart technologies are being installed in buildings to coordinate, monitor and control building functions such as: security monitoring, zip services, fire and smoke detection, alert system, maintenance programming, position reporting and communication. These systems can carry out financial audits, stocktaking and ordering of supplies each night utilising telecommunication. The supervisor is the main computer that controls all the outstations, logic controller and moderns contacting them through a dedicated wiring system using a digital code only (Chadderton, 2013).

Past studies (Ma et al., 2012; Papantoniou, Kolokotsa and Kalaitzakis, 2015), have also proved that installation of lighting sensors have helped in energy saving of 13.0- 64.0% in existing buildings. The usage of BEMS through building optimisation and control algorithm for HVAC system resulted in 40kWh/m<sup>2</sup> energy saving and occupants' thermal comfort improvement.

Commercial building owners and facility managers should consider the option of such technological interventions for improving the office BEP. Likewise, it is guaranteed that the information from smart building helps facilities managers and staff to be pro-active, and engrossed in all facets of building management including energy usage. Although it called for innovation, customer intimacy, behavioural change, timely communication, training and transformation of middle management and building managers; as the demonstrated value-benefits of these interventions out-weighed the investment cost (Tanneja, 2014).

## *II. Zero Carbon Energy Sources*

The sun's energy absorbed by the earth and its atmosphere runs the planet's weather circle, which drives the energy use globally (Bahaj, 2005). Hence, renewable energy (REN) is of an infinite stock. The Sustainable Energy for All (SE4ALL) tracking framework defined REN as: energy from natural sources that are replenished at a rate faster than they are consumed, including hydro, Bioenergy, geothermal, aero thermal, solar, wind, and ocean (Yumldella, 2012).

The use of solar PVs and micro-wind turbines has become very prolific including well-publicised renewable micro-generation technologies. According to the IEA, (IEA, 2012), REN sources contribute  $24.7 \times 10^{12}$  kWh out of the world total primary energy supply of  $147.9 \times 10^{12}$  kWh (1217Mtoe), about 16.7% of primary energy supplied in 2009.

Power generation from renewable sources also increased from 2,300 terawatt-hours (TWh) in 1990 to 4,160 TWh in 2010, consequently the global consumption of renewables grew from 40 exajoules (EJ) in 1990 to almost 60 EJs in 2010 (Yumldella, 2012).

REN grow continually despite policy uncertainty in source countries. The share of global REN supply estimate is about 17% of global final energy consumption. It accounted for 50% of estimated 208GW of new electricity installed in 2011. Hence, renewable energy electrical power capacity worldwide reached 1,360GW (+8%) in 2011 alone (Adib, 2012).

The EU's 2009 Renewable Energy Directive had laid down a target for the UK to provide 15% of her energy use from REN sources by 2020. However, as at 2012, UK's renewable energy supply was 10.8% of national energy consumed; and her National Renewable Energy Plan includes a trajectory that planned to increase its renewable share to 31% of supply by 2020



(Foxell, 2014). Finally, the current study review of these REN inventions is contained in appendixes 4A-F.

### 2.7.2 Managerial Interventions

Various management interventions such as: BEM, comfort and operational settings; strategic management; FM, SP and decision-support models, have been advanced in extant literatures.

#### *I. Strategic Energy Management*

The quest for organisations to achieve competitive advantage over other rivals, informed the concept of strategy management. Pitts (2006) suggests the use of strategy that contains the thoughts, plans, and support that firms could apply to compete successfully against their competitors. Organisations require strategic competence in EE planning and administration, global awareness, managing stakeholders and leveraging technology to have a competitive advantage (Pitts, 2006). Hence, effective energy management requires the use of tools and methodologies that support the strategic decision-making process of selecting the best EE interventions (Doukas, Nychtis and Psarras, 2009).

Office building EEP and carbon footprint agenda should be integrated into the organisation strategic management process to satisfy organisational strategic imperatives (Pitts, 2006). Management should be committed in decisions and actions needed by the firm to achieve SEM. (Hitt, Ireland and Hoskisson R.E., 2015.); and determine both immediate and long term energy performance of their built assets. The uptake of environmental management system (ISO 14001), EN16001 standards and energy management system (ISO 15001; 2011) by organisations, is management commitment and action towards effective management policy intervention (Rudberg, Waldemarsson and Lidestam, 2013). In the UK about 11.0% of higher institutions have already taken up ISO 14001 as intervention policy (Altan, 2010).

#### *II. Strategic facilities management*

Facilities management (FM) is one of the fastest growing professions in the UK. Its market is worth more than 106.3 billion, with a growth rate of between 2% and 3% till the year 2012 (Elmualim et al., 2010). The growth of this industry is expected to continue with building information modelling (BIM), software, and IT playing dominant roles with FM in managing BEU presently and in the future. The concept of sustainable facilities management evolved

recently in parallel with the overarching concept of sustainable development; and the growing appreciation of the scale of predicted climate change (Ibid).

FM is a “profession that encompasses multiple disciplines to ensure functionalities of the built environment by integrating people, place, processes and technology” (IFMA, 2016). Consequently, SFM involve facilities manager interactions with core business to ascertain likelihood future change to business due to external influences like competitors’ plans. It also includes scanning for future external change (new techniques, ideas or legislations), affecting FM; and providing a policy framework as the basis of decision-making within the FM department (Barrett and Baldry, 2003).

Due to increasing awareness and legislatures on energy use and carbon emissions reduction, many corporations now developed sustainability policies as integral part of company’s corporate social responsibilities (Elmualim, Valle and Kwawu, 2012). Therefore, Facilities managers are saddled with the responsibilities of strategic sustainable policy formulation, implementation and monitoring within the organisation.

### *III. Sustainability Policy and FM as drivers*

Various works have advanced SP and FM as separate drivers for improving BEP. Some studies (Elmualim et al., 2010; Abigo et al., 2012) etc., emphasised on the relevance of SP and FM separately, as well as barriers to their applications in sustainable management of buildings.

Elmualim et al., (2012), studied the perception of FM professionals on the eight drivers and 14 issues relating sustainability policy and facilities managers’ responsibilities. They used a questionnaire and interview surveys for data collection. The results of this study show that: waste management and recycling, energy management and carbon footprint ranking highest among SP issues; and legislation, corporate image and organisation's ethos ranked highest for drivers.

Abigo et al., (2012), developed a framework for embedding sustainable FM in the management of public buildings in Nigeria. The study used literature review and questionnaire survey for data collection. The framework comprises of six phases that are interconnected and perfect procedure for the embodiment of SFM. These phases are public awareness & enlightenment,

training & education of professionals, create sustainable regulations/ regulations, develop written sustainable policy, incorporate sustainable practices and enforce sustainable practices.

The study (Ibid), concluded that regulations/ legislations and targets by the UK government have aided the implementation of SFM in the management of public buildings, therefore, advocates the adaptation of UK government actions including regulations/ legislations for Nigeria. This study, though very close to this current research, did not also investigate the actual contributions of SFM to building energy performance. It only formulated and developed a theoretical account for establishing SFM practice for managing public buildings in Nigeria.

Ikediashi et al., (2012), used literature, questionnaire and interview surveys to investigate the degree of commitment and barriers to sustainable facilities management practice among corporate organisations in Nigeria. Their study identified training and tools, lack of relevant laws and regulation, and deficiency of awareness as three primary barriers to FM practice in Nigeria; and mixed commitment from the organisation of FM practices. The research did not investigate the potential and the absolute benefit of FM and sustainability in building energy use. The awareness of perceived and absolute benefits of FM and SP by the organisation is very crucial in the level of commitment expected from them.

Elmualim et al., (2010), used an online questionnaire survey to ascertain the commitment of facilities managers to the cause of sustainability agenda. They identified time constraint, lack of knowledge, and lack of senior management commitment as barriers and commitment to the introduction and practice of sustainable FM principles. They also found out that customer, physical & historical and financial constraints, and organisational engagement as well as lack of training, tools, knowledge, awareness and senior management commitment are the hindrances for effective management of sustainability responsibilities in the organisation.

These findings are consistent with each other on the issue of SP and FM, nevertheless, none bridge the gaps identified in this current research. A core and integral-tool is needed in any organisation at strategic management and operational levels. This will serve as a propelling factor for the organisation in achieving target performance measures for its facility energy use. Hence, combining embedded sustainability policy and strategic FM as strategic tool could help reduce the facility's energy use, cost and CO<sub>2</sub> emissions.

#### *IV. Operational Management Techniques*

The use of controls for boiler sequence, cooling and heating, motor, and thermostat regulator have been cited in past studies. Several decision-support models have been advanced as management interventions in extant literatures (Altan, 2010; Ma et al., 2012). Taking over behavioural control from occupants via use of technology has recorded success worldwide.

Previous study (Altan, 2010), on controls has proven to have achieved up to 50.0- 95.0% success level with about 5.0- 50.0% energy savings averagely within UK's higher education institutions. The study results also indicate that the cost of these controls ranges between < £1,000- £10,000. Particularly installed lighting control systems linked to daylight via arterial lighting has shown to have reduced BEU while it also meets the occupant's requirement.

A simulation study (Boyano, Hernandez and Wolf, 2013), of office buildings in Tallin, Madrid and London; on 50% partial and 100% full lighting control, and availability of natural daylight (based on 30% and 50% glazing), indicate tremendous energy savings in cost and consumption. Results for the three cities showed energy saving range of 10.0- 18.3% for partial control at 50% glazing, and 20.0- 36.6% for full control at 50% glazing. Besides the percentage cost savings for these scenarios ranges from 15.4%- 47.3%. It established the efficacy of controls as management interventions for office buildings, thus, these applications could be practiced managing Nigeria office buildings.

Similar studies based on simulations (Ma et al., 2012; Dubois et al., 2015), also indicated that BEMS and decision-making support models results in energy savings for office buildings. Occupancy controls have shown up to 20.0- 93.0% energy saving potential. Whilst, decision-support models have aided: life cycle cost assessment, cost-benefit analysis, identification and evaluation of interventions, evaluation of energy savings, etc. in past studies (Doukas, Nychtis and Psarras, 2009; Juan, Gao and Wang, 2010).

The current study's model is a decision-support model; and there is dearth of such adaptive model for SSA office buildings. It helps to evaluate the critical elements for improving BEP that could be applied to inform technical, functional and management decision-making.

### 2.7.3 Behavioural Interventions

Global awareness on BEP is increasing due to GHG emissions and climate change. Awareness, campaigns, trainings and behaviour change tool (BCT) have been advanced as behavioural interventions for improving BEP in existing literatures. Public awareness of climate change has proven to stimulate organisations to consider strategies for reducing energy consumption both for economic and environmental reasons (Schelly et al., 2011; Lucon et al., 2014). Also, behaviour, lifestyle and culture have critical impacts on BEU. In the developed countries, it has been shown that, behaviour influenced by awareness of energy and climate issues can reduce demand up to 20% in the short term and 50% of present levels by 2050 (Lucon et al., 2014).

The lack of awareness on BEE, often lead to energy consumption waste in existing building stocks. A past study (Masoso and Grobler, 2010), showed that about 50% more energy is used during non-working hours than working-hour in office buildings in Botswana and South Africa. This was due to the habit of not switching-off; and about 23% of the buildings' energy used that came from the unoccupied part of the weekend-ends. Hence, it can be anticipated that increased awareness of BEE and climate change norms could help achieve a drastic BEU reduction in sub-Sahara African.

Several interdisciplinary studies on energy consumption behaviour (ECB) have been undertaken since the 1970's oil 'bubble-burst' crises. Some of these are: technology assumption models (diffusion theories, theory of planned behaviour, social communication etc.); and pro-environmental psychology (influences of information, pro-environment, attitude, value-belief-norms); etc. These numerous studies seek to interpret human conduct on energy usage, identify motivations and hindrances for efficiency, improve awareness, and the importance of technological intervention programmes (Stephenson et al., 2010).

The desired 'step-change' to EE behaviour requires knowledge of behaviour, drivers as well as barriers that influences consumer's energy decision-making; and application of this knowledge in intervention programmes (Stephenson et al., 2010; Abbas, 2012.). The knowledge of systems and behavioural theories of decision-making will assist in this respect, and understanding its drivers will aid the adoption of more EE practices.

#### *I. Concept of Energy Consumption Behaviour (ECB)*

Previous studies (Martiskainen M., 2008; Stephenson et al., 2010), have elucidated on the meaning of ECB. User's behaviour based on energy electricity and gas usage in office building, include actions such as using lighting, HVAC equipment, and electrical appliances (computers, washing machines and personal electronics), etc. Also, ECB are decisions and actions taken in our homes and offices that have direct links to either electricity or gas consumption at the point of usage. Energy consumption is not behaviour but rather a consequence of behaviour (Martiskainen M., 2008).

Behaviour could sometimes be characterised primarily in terms of technologies acquired or adopted; consumer's use of energy related equipment; consumer's aspirations (healthier environment, cleanliness); and interrelationship between these factors (Stephenson et al., 2010). Several studies (Martiskainen M., 2008; Masoso and Grobler, 2010), have further classified energy efficiency (saving) behaviours into two groups as: efficiency behaviours a one-action behaviours inform of investment in envelope insulation, double glazing etc.; and curtailment behaviours, which are repetitive efforts like switching-off of lights and appliances etc.

ECB are influenced by both personal and societal factors. User's ECB are influenced by personal internal factors like attitudes, beliefs and norms etc., and external factors like cultural practices, regulations, institutional etc. Human's behaviour includes habits and routines, which are actions taken without really having to think about them. These habits and routines are: switching-on/off, electrical appliances' use, and setting the thermostat level of our cooling and heating systems. These authors agreed that habits and routines are ingrained in people behaviours hence, difficult to break (Martiskainen M., 2008).

Hence it is vital to understand the critical attributes of user's behaviour that influence energy usage in office buildings. This will inform the type of EE behaviour interventions that will be suitable for occupants.

## *II. Theories of Users' ECB*

Human behaviour and environmentally significant behaviour are complex phenomenon due to diversity of influences on them. Energy conservation behaviours are believed to be impacted by social-demographic and psychological variables (Ndubisi et al., 2013). Besides, the contributions of social-demographic variables and attitude to behaviour (Ajzen, 2002;

Mafimisebi, Jones and Nwaubani, 2015) etc., have been well researched. Likewise, these studies on human behaviour have led to various theories and models of behaviour toward ECB.

a. Attitude-Behaviour-Context Model

The Attitude-Behaviour-Context model of environmentally significant behaviour is based on the understanding that behaviour is a function of an organism and its environments. Thus, behaviour (B) is an outcome of interaction between personal attitudinal variables (A) and contextual variables (C). Our personal attitudinal variables include beliefs, norms, values, and a tendency to act in certain ways. Whilst, contextual factors include: monetary incentives and cost, physical capacities and constraints, social norms, institutional and legal factors (Martiskainen M., 2008).

Originally, the Attitude-Behaviour-Context theory does not recognise habit, Stern asserts (Ibid) that old habit must be broken down for human beings to form new habits. However, this has been proven to be otherwise, as a recent study indicates that traditional habit has impact on new attitudes. Ndubisi et al., (2013) used the awareness, training about technology to examine the impact of attitudinal variables and contextual factors on energy conservation potential of people in India. Findings showed traditional habits and beliefs played important roles influencing attitude formation in rural household. Contrariwise, intention and perceived behavioural control (PBC), is believed to be the most critical determinant of actual behaviour are lacking in the Attitude-Behaviour-Context theory.

b. Theory of Interpersonal Behaviour

The Triandis' theory of interpersonal behaviour, is another environmentally significant behavioural model. Martiskainen (2008), explained that it is based on intentions, habits and facilitating conditions (external factors) which influences our behaviours. Human behaviour at any time is a product of intentions, habits (inherent), situational factors, and the immediate (external) environment. A person's intention is influenced by rational thoughts, social, normative and emotional factors. The model recognised the belief of what people think (beliefs) outcome of their activities will be. For instance, if I switched-off my heater I will save electricity and keep money. Nevertheless, it does not recognise PBC as an attribute of human conduct; therefore, is not suited for the current field.

c. Value-Beliefs-Norms Theory

Value-Belief-Norm is based on Schwartz's theory of Norms Activation, which is strongly underpinned by the Altruistic Behaviour Model. Altruistic Behaviour Model is linear with positive/ negative consequences for other members of the environment. The Schwartz's Model of Norms Activation is based on two sets of beliefs. These are: an individual must be aware of the consequences of his actions towards the subject of norms; and the individual must have a feeling of responsibility for causing or preventing these consequences (Ibtissem, 2010).

Ibtissem (2010), used the theory of value-beliefs-norms (VBNs) to explain energy conservation behaviour in Tunisia. It was underpinned by the principle of activation of personal norms by the values and beliefs of individuals. He confirmed that the behaviour of energy conservation is positive, and as well as, significantly connected to personal norms. This he said confirmed both Values-Belief-Norms and Norms-Activation theories (NATs), which postulate that personal norms represent the determinant factor which is the closest to energy consumption behaviour.

Both theories nevertheless, put emphasis on norms and self-predictions, which contributes significantly to human behaviour; they also lack intention that has been proven to be a better determinant of behaviour in a past study (Armitage and Conner, 2001a). Therefore, could not be adapted for use in the current study.

#### d. Theory of Planned Behaviour

The theory of Planned Behaviour has been extensively dealt with in literature lens. It is an extension of the Theory of Reasoned Action that include measures of control belief and perceived behavioural control (Armitage and Conner, 2001a). Additionally, the theory planned behaviour is established upon human's action being determine by three kinds of considerations: beliefs about the likely outcome of behaviour and the evaluations of these outcomes (behavioural beliefs); beliefs about the normative expectations of others and motivations to comply with these expectations (normative beliefs); and beliefs about the presence of factors that may encourage or discourage the performance of the behaviour, and the perceived power of these factors (control beliefs) (Ajzen, 2002).

Individual weighting by Ajzen, indicated behavioural beliefs often produce favourable or unfavourable attitude toward behaviour; normal beliefs always result in perceived social pressure or subjective norms; and control beliefs lead PBC. While in combining these factors,



attitude toward the behaviour, subjective norms, and PBC lead to the formation of a behavioural intention.

Beliefs play a critical role in the theory planned behaviour. They provide the cognitive and effective foundation for attitude, subjective norms, and perception of behavioural control. Behavioural beliefs are assumed to determine attitude towards behaviour, but are not assumed to determine the direct measure of attitude. Also, normative beliefs determine subjective norms, but not a direct measure of subjective norms, whilst control beliefs determine PBC, but not the direct measure of PBC. Attitude towards a behaviour is a person's overall evaluation of performing the behaviour in question (Ajzen, 2002).

Armitage and Conner (2001), concluded that attitude, subjective norms and PBC accounts for significantly more of the variance in individual's desires than intentions and self-predictions. Also, they opined that intention and self-predictions were better predictors, whilst subjective norm construct is a weak predictor generally. Thus, the current study found that TBP has more encompassing attributes of behaviour than others; also, its emphasis (attitude, norms and PBC) and predictive power of intention and self-prediction makes it more suited for the study.

### *III. Non-Technical Interventions*

#### *a. Awareness*

Awareness program based on knowledge and information needs has been found to be a very useful intervention in the current study. Particularly, interventions based on the theory planned behaviour that use information strategies have led to behavioural change. A past study (De Bruijn et al., 2007), found that providing people with information about the risks and outcomes of their behaviour led to more positive attitudes and intentions towards behavioural change in the case of fruit consumption. Similar intervention could yield the same result when applied to ECB in office buildings.

A study (Eichholtz, Kok and Quigley, 2010), also, shown that information programme like Energy Star building labelling has an intangible impact on buildings' value. The finding revealed that rated building command higher rental and selling costs. It shows that green building is about \$5.7million more than comparable untreated building in the same location.

#### b. Campaigns and Programmes

Past study (Parnell and Larsen, 2005), established that EE programmes and campaigns success rest upon users' self-interest motivations, relying on occupants existing knowledge and using a greater share of user's aggregate cognitive capacity to better effect. Also, EE programmes should incorporate contextual factors and useful campaign tool like the energy label programmes. Another study (Schelly et al., 2011), found that a high school saved about US \$76,000.00 at approximately 50.0% reduction in school buildings between 2000 and 2007; due to ENERGY STAR label certification, communication and other conservation schemes.

#### c. Training

There is a need for training occupants and operator of installed EE technologies in office buildings. The importance of internal and external training for energy assessor at the implementation phase of EE programmes has been emphasised. Hence, training is among the other tambourine category (animating via information, promotion, competition and demonstration project), under the assessment framework for policy mechanisms description and instrument classification (IEA, 2011).

#### d. Behavioural Change Tool (BCT)

A BCT based on a holistic approach to pro-environmental behaviour leads to behavioural change in the organisation. Previous study (Schelly et al., 2011), established that perceived efficacy, behavioural expectation could modify staff behaviours and lead to energy saving in the work place. A BCT based on structural changes, individual behavioural changes and organisation culture underpinned by combination of recycling and energy conservation programmes resulted in Rocky Mountain High School scheme success of 50% energy consumption savings from 2000-2007. Another critical success factor of the college's scheme: is leadership, communication and a sense of efficacy.

## 2.8 BUSINESS CASE FOR IMPROVING BEP

### 2.8.1 Built Asset Management

The building sector accounts for large energy use due to degradation of its components and declining performance over the years. Significant energy saving can be achieved based on improvement of the performance of existing building's systems via continuous commissioning.

It involves the process of energy assessment, benchmark and energy retrofit based on a planned regular basis. The assessment and benchmarking process is important for tracking, monitoring and detecting abnormal energy consumption behaviour of buildings (Zhengwei, Yanmin and Peng, 2014).

The IPCC 5<sup>th</sup>AR 2014, confirmed that the technology and retrofit are effective carbon interventions. It asserts that development in technology and retrofit of very low-zero energy buildings, with comparable low marginal cost and shorter payback periods could yield meaningful results. In existing buildings, 50-90% energy savings have been achieved through deep retrofits globally. Strategic planning of technological options, design and behavioural changes can help achieve reductions in BEU in new buildings (50%- 90%) and existing buildings (50%- 75%) (Lucon et al., 2014).

#### *I. Built Asset Management Strategy*

Asset management is a structured process that seeks to ensure best value for money from property assets in serving the strategic needs of local authorities or organisations. The Local Government Asset (LGA) guidelines illustrated the following as key features of property asset management: extensive capital and annual cost of upkeep; lifecycle management for achieving best value through use, maintenance and generation of incomes; and the long time to determine property needs, ensure procurement and provide them (RICS, 2008).

Strategic asset management thus, involves effective and efficient direction and utilisation of assets, both tangible and intangible, to sustain the business. It is a key component of business planning at a strategic decision-making level that entails corporate decision needs, the deployment of its assets and its future investment needs. Asset management contributes to core business resource planning by ensuring that the physical asset base aligned to organisation objectives, (RICS, 2008).

The RICS (2008), definition of strategic asset management covers production, facilities, fleets and IT infrastructure, etc. It defined property asset management as “a structured, holistic and integrating approach for aligning and managing over time: service requirements (strategic component); and the performance of property assets (operational component) to meet business objectives and drivers. It also described asset management as optimising utilisation of land and building assets portfolio in terms of service benefits and financial returns”, claiming that

strategic asset management for land and buildings ensure that the asset base of an organisation aligned with its corporate goals and objectives.

The impacts of climate change on the built environment, including the need for adaptation and mitigation have already been emphasised. The built assets, therefore require a strategic plan aligned with corporate goals and objectives in meeting climate change demands. Over the lifetime of a building, the operations and maintenance of costs are four to five times greater than the design and construction, (Lewis, 2012).

## *II. Managing Building Fabric: Adaptation and Maintenance.*

Several writers have defined and explained the difference between the terms used for the management and improvement of building fabrics. Maintenance, adaptation, refurbishment, conversion, renovation & restoration, continuous commissioning, and retrofit are known concepts commonly used interchangeably in the built environment. There are divergent views about each of these concepts. Cortgrave and Riley (Cortgrave and Riley, 2011), in their work explained the meaning of these concepts with definitions as follow:

*‘Refurbishment is the process of extending the useful life of existing buildings through the adaptation of their basic forms to provide a new or updated version or the original structure. The conversion of buildings means, altering the use of the buildings without changes to the main structure of the buildings. Whereas, renovation and restoration are renewal and repair works carried out to address dilapidations to avoid further degradation of the buildings. However, retrofits are usually used for building services through fitting new and modern systems into an existing building’.* Riley and Cortgrave explained that refurbishment and adaptation are the same in meaning.

Right from the start of completion and occupation period, a new building starts to deteriorate and becomes obsolete over time. The process of decaying and deterioration of the building fabric and services begins immediately after completion and occupation. Hence, the need to undertake maintenance actions to ensure that building maintain its efficient performance level, and for the preservation of its financial asset (Ibid).

Maintenance thus, is the work carried out to preserve or restore equipment to the original condition or to a condition that can be effectively used for the intended purpose (BSI 1993;

APPA 2002, (Lewis, 2012). In this regard, maintenance is clearly differentiated in meaning and use of the concept of adaptation (refurbishment).

Douglas (2006), in his work explained that the word ‘refurbishment’ originated from two words ‘re’, meaning to do it again; and ‘furbish’, meaning to polish or rub up. He expounds that refurbishment is to give a building facelift or refit to improve its appearance and functionality. Therefore, refurbishment primarily involves the extensive maintenance and repair to upgrading the aesthetic and functionality of a building, together with major improvement to its fabrics and services. It may also involve lateral extension to an existing building.

He linked adaptation to refurbishment as he asserts that adaptation came from the Latin word ‘ad’ (to) and ‘apt are’ (fit). In this regard, adaptation is meaning ‘*work to a building that is over and above maintenance to change its capacity, which is any change to adjust, reuse or upgrade a building to meet new condition or requirements*’. Finally, Douglas argued further that refurbishment, rehabilitation, renovation and restoration lacks precise meaning in building conservation (BS 7913, 1998 cited in Douglas, 2006). Including that restoration is primarily restricted to major adaptation work on dilapidated, derelict or ruinous residential or commercial buildings, hence the use of adaptation as an all-embracing term.

Adaptation and maintenance are therefore different concepts that are useful in enhancing building sustainability, adaptive capacity to climate change risks and its low energy use capability.

#### *a. Building Maintenance Management*

Maintenance management is often underestimated and has been under researched (Lewis, 2012). Though it has been acclaimed to have significant benefits. Organisations now seek to use strategic maintenance plan to make best usage of the technical and economic strength of maintenance of their constructions. Strategic maintenance plans are used for securing the effectiveness and efficiency of the management of maintenance operations (Cortgrave and Riley, 2011). The strategic management plan basically consists of planned and unplanned work to keep equipment or the building functioning. It does not include technical or economic improvement to a facility that was not an initial part of the building (Lewis, 2012).

#### *b. Planned Maintenance*

Planned maintenance includes preventive, predictive and reliability centred maintenance. Also, it is referred as any proactive maintenance action carried out to reduce the amount of reactive and emergency maintenance work (Lewis, 2012). Whilst, Cortgrave and Riley expound that planned maintenance are those works planned to take place at regular intervals to keep the building functioning at ultimate performance. Depending on the specific work, the programme might take place frequently or infrequently. Often, planned maintenance is aim at risks prevention for major failure and consequential damage to the elements of the building (Cortgrave and Riley, 2011). Furthermore, ASHRAE, 2009; (Lewis, 2012), suggested strategies for the effective use of planned maintenance for reducing operation costs as thus:

- ❖ Elevate the importance of energy management within the organisation by appointing an energy manager
- ❖ Focus on efficient operation and maintenance strategies
- ❖ Institute performance tracking and reporting procedure and practices, etc.

#### *c. Unplanned Maintenance*

This includes reactive and emergency maintenance that comes frequently (daily) as the need arises. Emergency maintenances are often unplanned for; therefore, they are unscheduled works that come with urgent action. Emergency maintenance actions are intended to: restore an equipment to perfect working condition; or removal of a fault condition that can interrupt normal activity in a building; or cause damage to the building including risks to users' health and safety. Also, since equipment is subject to wear and tears and/ or unexpected failure, it is not possible to eliminate this type of planning in an organisation, (Lewis, 2012).

#### *d. Reactive (Emergency) Maintenance*

Reactive maintenance includes emergency maintenance that often occurs daily because of repairs and breakdown of plant and machinery (Cortgrave and Riley, 2011). It involves replacing or repairing of breakdown equipment and responding to equipment deficiencies because of building users' complaints. Reactive maintenance is used interchangeably to run to failure or break-down maintenance; and used for non-critical equipment failure where failure is insignificant and the cost of replacement or repair is lower than the cost of the proactive maintenance monitoring technique for the equipment (Lewis, 2012).

#### *e. Cyclical (Routine) or Preventive Maintenance*

Cortgrave and Riley (2011), expatiate that this is the type of maintenance needed to keep the building and its installed services in good working condition. Routine or preventive maintenance is planned on routine and regular basis; and a separate part of planned maintenance. It involves the routine servicing of installed lifts and other HVAC installations, cleaning of drainage gullies, etc. in the building. Preventive maintenance can help evade majority of the problems associated with a reactive approach, but have the following disadvantages: it could be wasteful as some equipment could be replaced before it reaches its end life cycle; it does not prevent failure; it can introduce new problem not initially associated with equipment; and its programmes require large supply inventories and stocking (Lewis, 2012).

*f. Building Obsolescence and Redundancy*

The continuous functioning of a building is important as well its life span. Buildings are subject to varying degree of use and exposure, hence, threaten by obsolescence and redundancy over time. Douglas (2006), in his work clearly distinguished between building obsolescence and redundancy. He defined building obsolescence as ‘the degree of usefulness of a building relative to the prevailing current market conditions of similar building stocks; and largely govern by consideration for supply and demand factors’.

He expounds further that obsolescence is the process of a building going out of use, which is a transition towards the state of being obsolete or useless. It is a measure of an object usefulness over time, which indicates the propensity of ‘assets and operations to become out-of-date, outmoded, or old-fashion’. Thus, he asserts, is a function of human decisions rather than the result of natural forces. Hence actions can be considered to cut the relative obsolescence of a building and increase its utility.

Remoy and Wilkinson (2012), shared this view asserting that, obsolescence is problem of economic decay and social deterioration, where uncertainty and social insecurity manifests in form of vandalism and graffiti, break-ins and illegal occupancy. Whereas building redundancy means ‘surplus to use’, a situation where ‘buildings are no longer needed or are excess to requirement’, and it is primarily determined by demand factor. A building might be newly built and in excellent condition, but redundant due to surplus supply of its similar types that led to slump in demand.

Douglas (2006), elucidate that there is difference between building obsolescence and redundancy, hence are not synonymous. A building may be redundant at a time, but not obsolete for its planned use. However, obsolescence is often the trigger for building redundancy and redundancy is the result of it. Additionally, Douglas clearly enumerates the effects of the two concepts as thus: obsolescence is associated with dilapidation, partial disuse leading to redundancy or complete vacancy, and decline in value; while redundancy is associated with complete vacancy, prone to neglect and dilapidation, and vulnerable to vandalism including squatting.

The usefulness of a building and its current market value are two crucial factors that drive owners and facilities managers towards sustainable management of buildings. Hence, continuous refurbishment based on sustainable adaptive measures against obsolescence and resultant redundancies based on strategic maintenance are both considered in this current study.

#### *g. Building Adaptation*

British Standard (ISO 15686- 1:2000 cited in Douglas, 2006), identified refurbishment and upgrading as the major strategies to counter obsolescence and to a lesser extent avoid redundancy. They are actions to improve the usefulness of a building and keep it in perfect functional condition. Adaptation works such as alterations, extensions and refurbishment provides security for buildings.

Recent work by Jones et al., (2013), identified as a problem, the integration of future adaptation plans into the built asset management strategy. They opined that adapting to climate change is not often considered as part of routine maintenance and refurbishment actions, hence doubtful if UK strategic approaches such as climate change community, UK climate projects and risk framework can be successfully integrated into the built asset models, (Jones, 2012; Jones et al., 2013).

Despite this perceived gap, a sustainable adaptation of the building is still the key intervention for measures of improving the energy efficiency and reducing CO<sub>2</sub> emissions from existing building stocks. Remoy and Wilkinson (2012), agreed with this view by emphasising that building adaptation is a prudent method of reducing GHGs emission. It promotes urban intensification, retains embodied energy and promotes the usage of public conveyance. Also,



findings from their study indicate that, adaptation of office buildings can mitigate the effect of climate change in urban areas and enhance city for the next generation.

There are several reasons why owners and occupiers may want to adapt (refurbish) a building. Cortgrave and Riley (2012), explicate that a building layout may not fit into modern requirement, and refurbishment cost could be cheaper than newly built, are major reasons for adapting. Nonetheless, other principal reasons for refurbishment (adaptation) could be building failure and building obsolescence. They listed the reasons for building failure and the approximate portion of total failure factors in the UK based on BRE data on ‘Causes of Failure in Buildings’ as thus:

- ❖ Defective design, which accounts for 38% of building failures in the UK.
- ❖ Faulty construction is another major ingredient that caused about 23% of building failures in the UK. This is because of lack of skills and experience in modern technologies used for building construction.
- ❖ Faulty use is also causing about 8% of building failures. Owners or occupiers could undertake minor refurbishment like knocking down walls to create space without seeking expert advice, it could lead to structural failure that might potentially cause collapse, etc.

The Royal Institute of Chartered Surveyors (RICS) (Cortgrave and Riley, 2011), list the following factors that could lead building obsolescence:

- ❖ Aesthetic factor: some building becomes out-fashion early, ugly, or too old and antiquated leading to obsolescence.
- ❖ Economic factor: building as financial asset have economic value placed on it, once this start reducing lead to decline in their income generation, that building ceases to be a viable financial asset.
- ❖ Physical/ legal factors are situations where, the abilities for buildings in meeting new regulatory requirements (energy conservation, accessibility etc.) becomes too costly or unachievable, obsolescence may set for such buildings
- ❖ Technological factor is another influence that could lead to obsolescence in buildings. A building superstructure inability to adapt advanced technology may be a sound reason for obsolescence.

Douglas (2006), concluded that, all buildings are involved in varying degree by some form of obsolescence and inefficiency. This is often due to deficiency in the fabric and installed services resulting from their inability to meet current regulations and handle technological changes. Hence, building adaptation schemes can classify into complete, major and minor refurbishments, and redevelopment works (Cortgrave and Riley, 2011), as follows:

- ❖ Complete refurbishment involves replacement/ change of all other elements (components) except the foundation, floors, and superstructure of the buildings that will remain.
- ❖ Major refurbishment, which involve alterations to fabric such as floor tiles, suspended ceilings, raise floors and internal partition walls; and replacement of installed plant and services in buildings.
- ❖ Minor refurbishments include replacement or improvement of plant and services, repainting, replacement of floor rugs, carpets, and other redecorations.
- ❖ Redevelopment works involve changes to building components, except the façade and foundation of the façade.

## 2.8.2 Corporate Social Responsibility (CSR)

### *I. CSR and Sustainable Performance of Business*

Business play a critical role in the global carbon mitigations agenda. Evidence indicates that about 81.2% of the world 500 largest companies contributed up to 3.6billion tons of CO<sub>2</sub>eq in 2009 alone, which is equivalent to the European Union annual emissions (Patenaude, 2010). CSR is the ideal for organisations taking-on the identity of corporate citizenry in response to social and environmental responsibilities to improve their performance.

Corporate social and environmental responsibility has been defined as the actions undertaken by organisations to maintain ethical and cultural norms of the society in which companies operate (Carroll, 1979). Carroll exposed that, social responsibility must encompass the economic, legal, ethical and discretionary expectations that the society has on the organisation at a given time to fully express the responsibility a business has for the society.

Firms have begun to see CRS as a strategic tool for integration of their social and environmental responsibility with economic strategies in achieving sustainable performance. Previous study (Tate, Ellram and Kirchoff, 2010), showed that firms that engage in social responsibility gains

positive financial benefits through cost savings from resource reduction and efficiency. They also improve their corporate image and stakeholder relations. Also, studies have shown that there is a positive association between corporate social and environmental strategies and sustainable performance of organisations.

Organisations achieve this goal through the global reporting initiative that seek to meet corporate goals and satisfy stakeholder demands. The world top 200 firms adopted the CSR reporting as part of social and environmental responsibility strategy (Handfield, Sroufe and Walton, 2005). Also, government regulations on building labelling has proved to impact the energy performance of buildings; and at the same time aided in determining the market value of green office buildings (Eichholtz, Kok and Quigley, 2010). Another study (Idowu and Towler, 2004), found that CSR reporting on UK's companies' disclosure information helped in energy consumption reductions, increase staff retention and customer loyalty, and improved quality and productivity.

Additional factors that propels CSR in achieving sustainable performance is firm's corporate image. Firms are forced to maintain environmentally responsible image by internal and external stakeholders. Stakeholders now influences firms' CSR programmes to sustain a positive and social responsible image (Tate, Ellram and Kirchoff, 2010), due to the increased awareness on climate change. This has helped in improving sustainable performance of businesses.

## *II. Business Models for Sustainable FM Strategies*

Previous studies (Then, 1999; Atkin and Bo-Christer, 2007; Jones and Sharp, 2007), have proposed several business models as FM strategies for the organisation's workplace.

Then (1999), identified the lack of an integrated framework that focus on the potential impacts and implications of business management trend and strategic decision-making on the provisions and on-going management of corporate resources. He developed an integrated framework that reflects the interactions between strategic business planning and operational asset management. Then, argued for a pro-active management model that consists of clear strategic guidance from senior manager and a clear measurable deliverable from operational management.

The model (Then, 1999), has a two-way direction from strategic intentions and directions of firm's future direction to the best method of achieving the desired outcomes in terms of resources and company's ongoing management. Thence, it is built upon tactical inputs from operational management and strategic inputs via strategic management in appropriating physical resource to meet supply and demand over time (Figure 2.11).

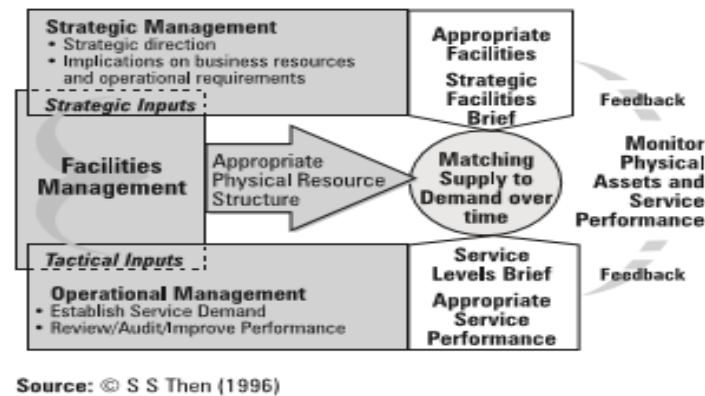


Figure 2.11: Then's Model: Roles of strategic facilities brief & service level

Then (1999), further transformed the model into business response to market factors as an integrated framework that is underpinned by people, technology and physical asset (Figure 2.12). The new integrated model has: emerging organisation profile, projected needs profile and affordable and effective solutions (feedback) phases. The emerging phase has strategic facilities planning, strategic asset management, asset maintenance management and facilities service management. The projected profile consists of evaluation procedures.

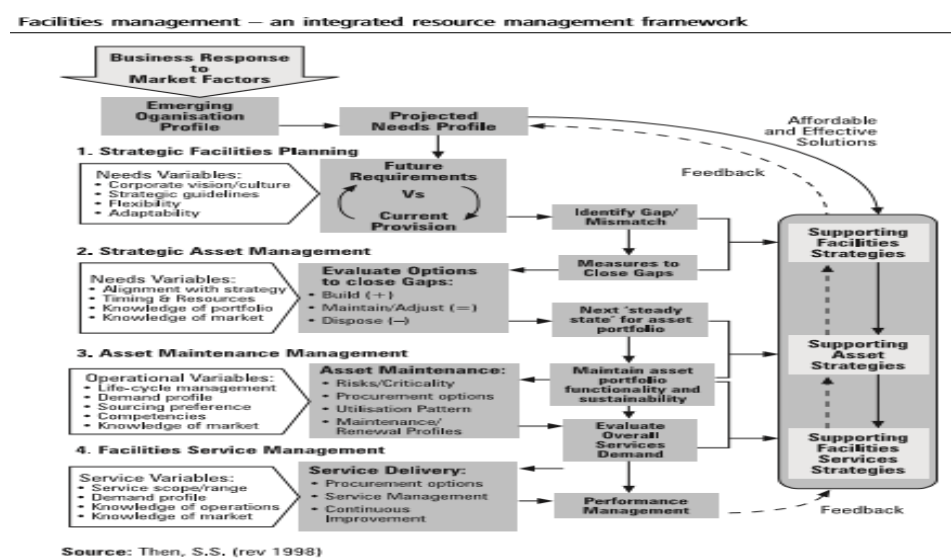


Figure 2.12: Then's FM integrated Resources Framework

The feedback phase comprises of supporting: facilities strategies, asset strategies and facilities service strategies. The model (Ibid), though, involves strategic and operational techniques, however, is a complex integrated model that is generic and not specific on BEP. However, current study could explore the identified interaction between strategic and operational management in framing-up critical factors for improving BEP in the study.

Another similar model (Atkin and Bo-Christer, 2007) is the FM process model based on the business process modelling (IDEFO: Integrated Definition for Function Modelling method). They suggested that the building owners' perspective (the client organisation) should be the rational basis for the evaluation of FM process. It emphasised that strategy should precede decisions on whether to outsource services.

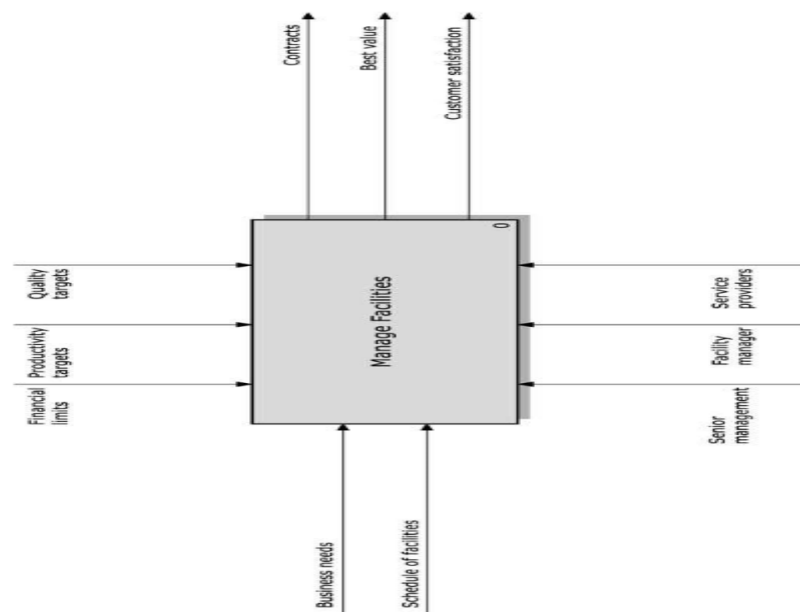


Figure 2.13: Atkin and B0-Christer: IDEF0 based Business Processing Model

The model (Atkin and Bo-Christer, 2007) comprises of seven phases: concept of IDEF0 method based on building process; the primary output phase based on control related to performance, productivity and financial limit; and FM strategy formulation base on analysing requirements, developing solutions, implementation, and monitoring service provision (Figure 2.13 and Figure 2.14).

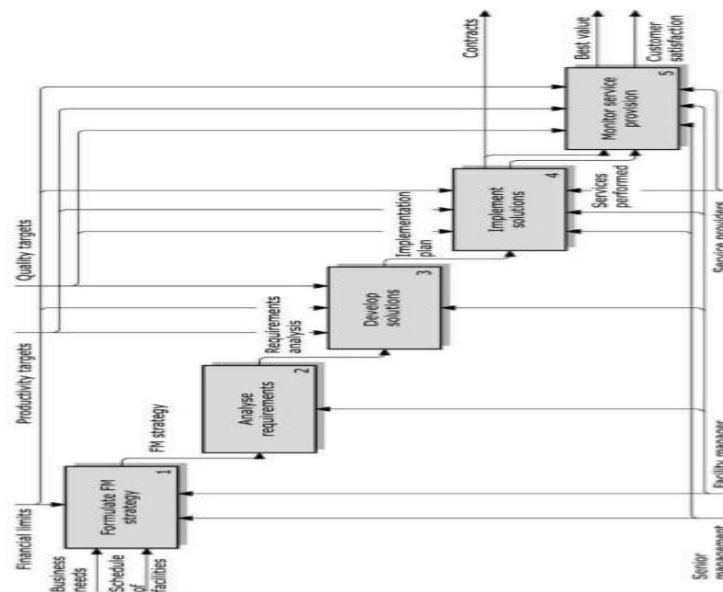
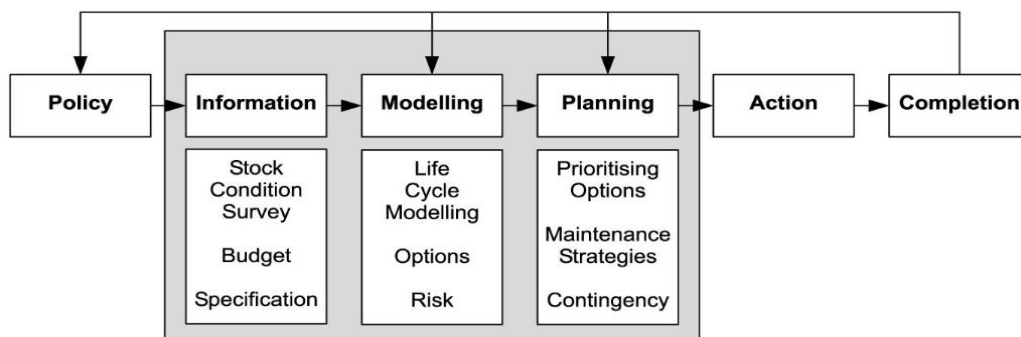


Figure 2.14: Atkin and B0-Christer: Top level view of the FM process

Other model's protocol is: analysis of organisation for solution; evidence gathering to support outsourcing or retention of in-house services; performance specification for in-house service; and monitoring of service provision. The building process model does not consider BAM and BEP, hence could not be applied to the current study.

Jones and Sharp's (2007), performance-based process model for built-asset maintenance is a sustainable FM strategy for the organisation (Figure 2.15). The model is built upon the BAM process model (Wordsworth, 2001), and it allows facilities managers (FMs) to understand the implication of maintenance actions before implementation. Hence, could inform strategic decision-making.



Source: Adapted from Wordsworth (2001)

Figure 2.15: the BAM process Model (Jones and Sharp, 2007)

It is an action research based model (Ibid), that involves six phases: policy/ strategy on critical success factors; need identification based on performance tool kits (productivity, commercial enterprise and asset value); and establishing cause based on analysis toolkits (inquiry, design, statistical/ experiential). The model protocol also includes: action statement involving project brief (project description, root cause, required improvement); solution development involves modelling toolkit (scenario, prioritization, maintenance impact models); and solution evaluation based on an impact toolkit (performance indicators and service agreement) (Jones and Sharp, 2007).

The model (Ibid), is directly connected with an organisation's physical asset, especially BAM, therefore, its principles deem relevant to the current study model. Hence, the current study modelling process is underpinned by the BAM process model and the four pillars of SD.

### 2.8.3 Work Place Management

The impact of workplace interventions on employee satisfaction and productivity has been expounded on in extant literatures (Veitch and Newsham, 2000; Wagner et al., 2007). Previous studies are in two divides in respect to controls (individual control and no control) on lighting, temperature and ventilation in the workplace.

Veitch and Newsham (2000) examined the impact of lighting control intervention on employee satisfaction and productivity on 47 office workers. Findings indicate that there was no difference between those that chose session (CS) lighting; and those that chose pre-session preferred (PP) lighting on employee performance and satisfaction.

Whilst, Wagner's study (2007), of 50 occupants in naturally ventilated office building in Karlsruhe, Germany, revealed that positive perception of indoor comfort can occur outside the temperature set limit within an air-conditioned building. Thus, adaptive comfort model predicts the thermal sensation and thermal comfort of occupants better than model with fixed limit to indoor temperature, if indoor and outdoor climate condition is put into consideration.

## 2.9 SUMMARY

The chapter reviewed the evidenced of CCH and concludes that climate is changing and the effect of these changes has impacts on buildings and occupants in the immediate and future. The study found that global earth's surface temperature warming up to  $0.85^{\circ}\text{C}^2$  ( $0.65\text{-}1.06^{\circ}\text{C}^2$ ) between 1880 and 2012. Inevitably, the atmosphere and ocean have warmed up, the amounts of snow and ice have diminished, and the sea level has risen. CCH exposes people, societies, economies and the ecosystem to risks of uncertain occurrences that are in the form of hazard vulnerability and exposure.

The literature also, linked CCH to consumption of fossil fuel and other sources of GHGs emitted; and established building as a major source. In 2010, 80% of the WPED are fossil-fuel based resulting in 49GTCO<sub>2</sub>-eq/yr GHGs emissions. Between 1970 and 2010, anthropogenic CO<sub>2</sub> emissions constitutes about 78.0% of total global GHGs emission; while buildings accounts for 56.6% of global CO<sub>2</sub> and 30-40% of global GHGs emissions.

The study found that buildings need to adapt to the changing climate risk and reduce CO<sub>2</sub> emissions to mitigate future change, in achieving sustainability. However, most of the existing buildings will still be standing for another 30-40years (by 2050); whilst the rate of replacement of new buildings is only about 1-2%. Likewise, intervention types and requirements for new construction differ from that of existing buildings. Hence, it will be more inexpensive to adapt old buildings compared to young ones.

The chapter studied EU's and UK's CCH policy response used in achieving building sustainability. Building energy codes and performances assessment guidance are the most used tools for improving BEP. The EU's instituted EPBD (2002/91/EC), has been stimulating the enhancement of BEP and CO<sub>2</sub> emissions reduction across Europe. The UK's response to the EU directive cumulated in the formation of the Climate Act 2008 (legislative instrument), which places stringent demands on BEP. The UK's strategically used DEC's and EPC's alongside UK's Government schemes and programmes as rollout interventions. Generally, they have yielded satisfactory results that could be replicated in SSA and Nigeria.

BEP is dependent on intrinsic factors that determine its energy use that are well established in extant literature. These factors are reviewed alongside critical contextual barriers and drivers



that affect BEP as established in the current literature. This also helped inform the variables that established current study's framework model.

The literature established that FMs developed a wide range of building adaptation and mitigation interventions. Hence, measures such as: the refurbishment of existing buildings; adoption of EE measures and renewable technologies are commonly used. Also, improvement of existing building's systems is now regarded as a part of strategic asset management to sustain the business.

Organisations now use, maintenance management via strategic maintenance plan (SMP), as their long-term BAM strategies. SMPs are now used for securing the effectiveness and efficiency of the management of maintenance operations. The study identified the various SMP, such as: planned maintenance (preventive, predictive and reliability centred maintenance); unplanned (Emergency maintenance actions); reactive maintenance (daily, emergency maintenance); Routine (preventive maintenance planned on routine and regular basis), as some of the BAM employed by FMs.

Impact of workplace interventions on employee satisfaction and productivity was examined. Current literature confirmed that FMs introduce a range of operational and behavioural interventions into the workplace. Two divides exist in extant literatures in respect to user controls (control and no-control): on lighting, temperature and ventilation in the workplace. The two-study type shows that both have their advantages, however, control of users is more prevalent due to the entrance of BEMS technologies.

Operational FM interventions to existing building stock (renewables, controls equipment, efficiency measures, and non-technical initiatives etc.), are found to be successful in the UK. Likewise, retrofits of existing buildings, incorporation of renewables, green roof, and fuel switching including efficient equipment are CO<sub>2</sub> mitigation strategies that could improve BEP. While, adaptive reuse is confirmed an effective BEP strategy and cheaper option, hence, these interventions could be adapted to Nigeria's existing building stocks.

The chapter studied the various management interventions such as: BEM, comfort and operational settings; strategic management; FM, SP and decision-support models by organisations. Also, the uptake of EMS (ISO 14001), EN16001 standards and energy

management system (ISO 15001; 2011), is management commitment and action towards effective BEP policy intervention. Particularly, SFM that involve FM interactions with core business' plans is a widespread practice. FMs are now saddled with the responsibilities of SSP within the organisation. Hence, combined SFM and SFM as a core integration-tool, is useful for organisations.

The current literature finally, identified the lack of detailed business models to support cost/benefit assessments as a major barrier to interventions' implementation in practice. An integrated BEP framework that builds upon the BAM process; allows FMs understand the implication of intervention actions before implementation; a pro-active management model that could inform strategic decision-making; and indicates strategic guidance and measurable deliverables is lacking. This research project addressed these problems by developing an assessment framework underpinned by the four pillars of sustainability that enables owners and FMs identify appropriate BEP solutions.

### 3 Chapter Three: Theoretical Framework Model

#### 3.1 INTRODUCTION

This section discusses the study framework and its operation. It expounds on how the various variables (reflexive indicators) of the framework model fit into a whole-system; and how they will be operationalised. Also, the chapter illustrates how the framework links energy with sustainability goals, interventions, and facilities management. Whilst, it further explains how the framework, as operational guidance; could help FM and owners undertake energy assessments and improve the EE of commercial buildings.

#### 3.2 BACKGROUND

The review of the theoretical framework is undertaken from the perspective of the theoretical knowledge established in previous section. The framework was developed through literature review based on insight from industry experts. The priori structure provides the study framework, its statistical data analysis, and the interpretation of the results (Brown and Pitt, 2001).

The examination of relevant worldwide theoretical concepts and models were diagnosed under seven contextual lenses of the framework; and interventions derived from analysed data. Hence, the theoretical framework is supported by theory triangulation via context of: operational, policy, cultural, management, business practices, barriers/ drivers, and climate as underlying constructs (factors) that drives building energy efficiency performance (BEP) (Figure 3.1). The basis for these seven concepts is underpinned by the aim of the current study, which is to: develop an assessment and benchmarking framework that will enable owners and facilities managers to identify appropriate operational, technical and behavioural solutions to improve the EE in existing buildings in Nigeria and UK.

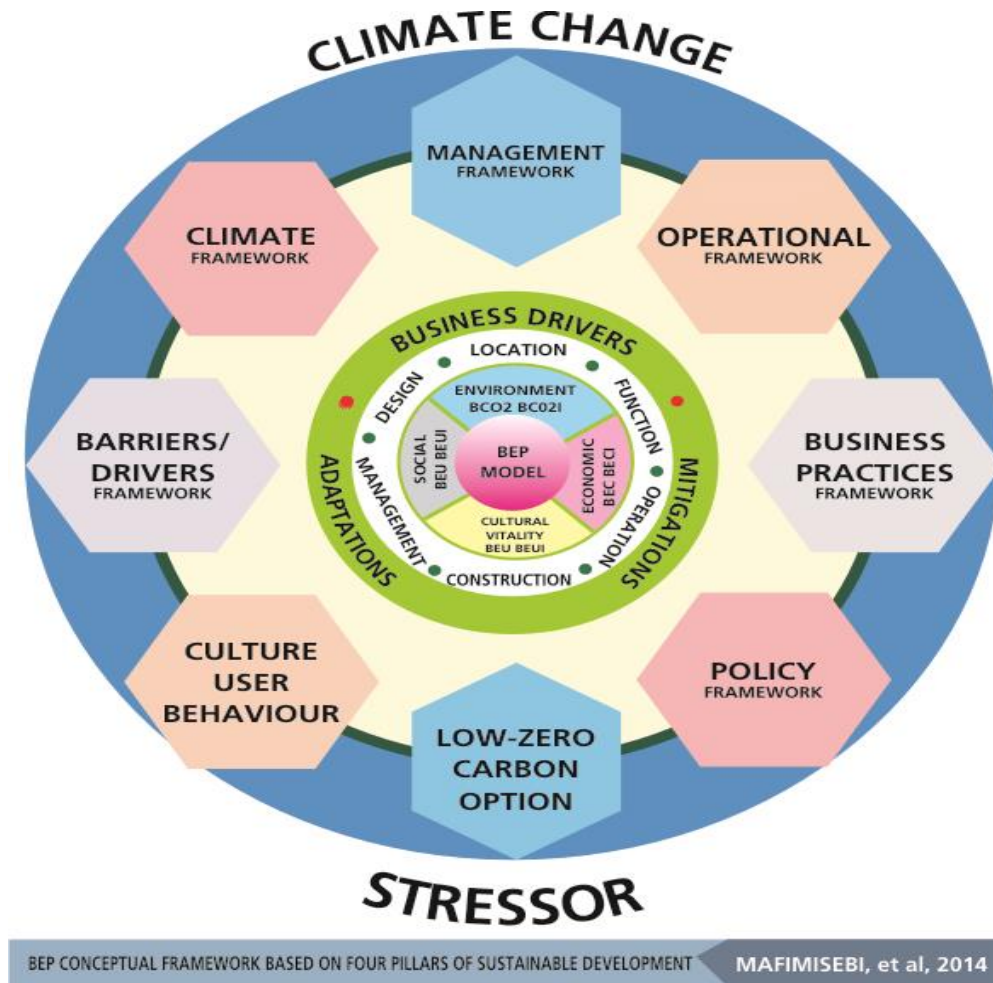


Figure 3.1: Study Conceptual Framework based on Four Pillars of SD.

The model draws its strength from application of built asset management theory (Jones and Sharp, 2007), and FM's integrated resource management model (Then, 1999). The need for energy assessment for improvement of BEP depends on its impact on organization's critical success factor. Hence, the BEP is based on the holistic perspective of investigation of factors influencing energy use during building life-cycle process; with a pro-active clear strategic guidance and measurable deliverables. The goal is to be analytical in splitting up the real problems associated with BEP in Nigeria into smaller sub-systems (units); and isolation of individual causal train as best fit in a final model (Bertalanffy, 1998). It aimed to serve as a practical decision-making tool based on tactical-strategic thinking for FMs and owners (Drack and Schwarz, 2010).

### 3.3 MODEL OVERVIEW

Sustainable building management (SBM) has direct impacts on BEP. Aging of buildings often leads to obsolescence and redundancy. Buildings installed HVAC efficiency decreases and fabric insulation gets weakened due to aging, thus, increases poor energy performance and building energy demand. This reinforced the demand for building sustainability in achieving optimal BEP over its lifetime. Moreover, current literature has advanced the importance of buildings to adapt to the changing climate risk and reduce CO<sub>2</sub> emissions to mitigate future change.

The need to study how organisations handle their respective building stocks becomes imperative. SBM is the foundation on which climate change mitigation and adaptation could be entrenched in organisations (Wakabayashi, 2013; Junghans, 2013; Jones et al., 2013). Hence, the model uses the identified factors as a SBM performance indicator of a BEP.

Central to the BEP model in fighting CCH, are the six indicators used to measure performance and advance low carbon goals for existing building stocks. The six indicators are the intrinsic factors that measure the phenomenon of BEU and BEP. These indicators: building energy use (BEU); building energy use intensity (BEUI); building CO<sub>2</sub> emission (BCO<sub>2</sub>); CO<sub>2</sub> intensity (BCO<sub>2</sub>/m<sup>2</sup>); building energy cost (BEC); and energy cost intensity (BEC/m<sup>2</sup>), were used to measure case buildings BEU and BEP. This satisfies the four sustainable criteria (environment, economic, culture and social), for management of low carbon buildings. However, they are assessed separately from other contextual issues based on NPI and EPL techniques via BEU data.

Extant literatures also, indicated that the intrinsic variables depend on building design, construction, location, function and management factors as underlying issues that have direct an impact on BEP. The current model is suited for existing commercial buildings; hence these factors are integral part of the framework; as their impacts are reflected in other contextual factors in the model. For instance, the impact of location, function and management are considered also under climate and management contexts respectively. Nevertheless, organisations need business drivers to curtail the impacts of CCH on BEP and reduce CO<sub>2</sub> emissions. Hence, adaptation and mitigation alongside organisation goals are key strategic drivers for improving BEP based extant literature findings (Jones, 2002; Remøy and Wilkinson, 2012).

Occurrence of case BEU and BEP are determined by different circumstances, such as: climate, barriers/ drivers, business practice, culture, regulatory policy, LZC-intervention, management and operations. These contexts are the latent variables (Figure 3.1), and could be measured as indicators of the whole BEP framework. In each sub-model (sub-unit), the context (latent) variables (constructs), are measured indirectly through individual's reflective indicators (Figure 3.2).

The current literature has identified CCH as a global stressor (Shibuya and Croxford, 2016; Li, Hong and Yan, 2014) that affects BEU and BEP during its life-cycle phases (design, construction, and operations). Hence, it is identified as the overarching factor that affect all types of building, irrespective of location and usage. The organisation's BEP management concerns focus on model's factors based on CCH outlook, as an overall critical stressor. This serves to encapsulate both the tactical and the strategic concerns that FMs and owners should consider as an integral of the study's BEP framework model.

### 3.4 MODEL'S CONTEXTUAL VARIABLES

The BEP model contextual variables are the extrinsic factors that influence BEP. They are assessed through questionnaires via Likert's scale weighting and interviews. The measurement helps to contextualised BEP in a wider understanding of the barriers and drivers, including legislation that reflects the differences between Nigeria and the UK (Figure 3.2).

The hexagonal box for each lens (context) indicates that they exist individually as units (sub-systems) within the whole model (system). They are further connected with green lines, indicating the interrelationship amongst them. Also, the model is a multivariate linear model representing group of variables (constructs and indicators) that are both mutually dependent and exclusive. Hence, there is no definitive 'start' or 'end' point, which indicates fluidity of the initial framework (Organ, 2015).

The BEP assessment model is like the BAM process model. BAM model hinges maintenance decision-making on its impact on organisation's critical success factor. It prioritises condition survey as a central decision-making process; and is underpinned by the process illustrated in the previous chapter (Wordsworth, 2001; Jones and Sharp, 2007). Also, current study

framework is informed by the interactions between strategic business planning and operational asset management used in Then's integrated model (1999).

Current model therefore, uses operational energy assessment, management policy and strategic drivers as conditions for improving BEP. Consequently, the contextual variables and their interactions are informed by prior knowledge as thus (Figure 3.2).

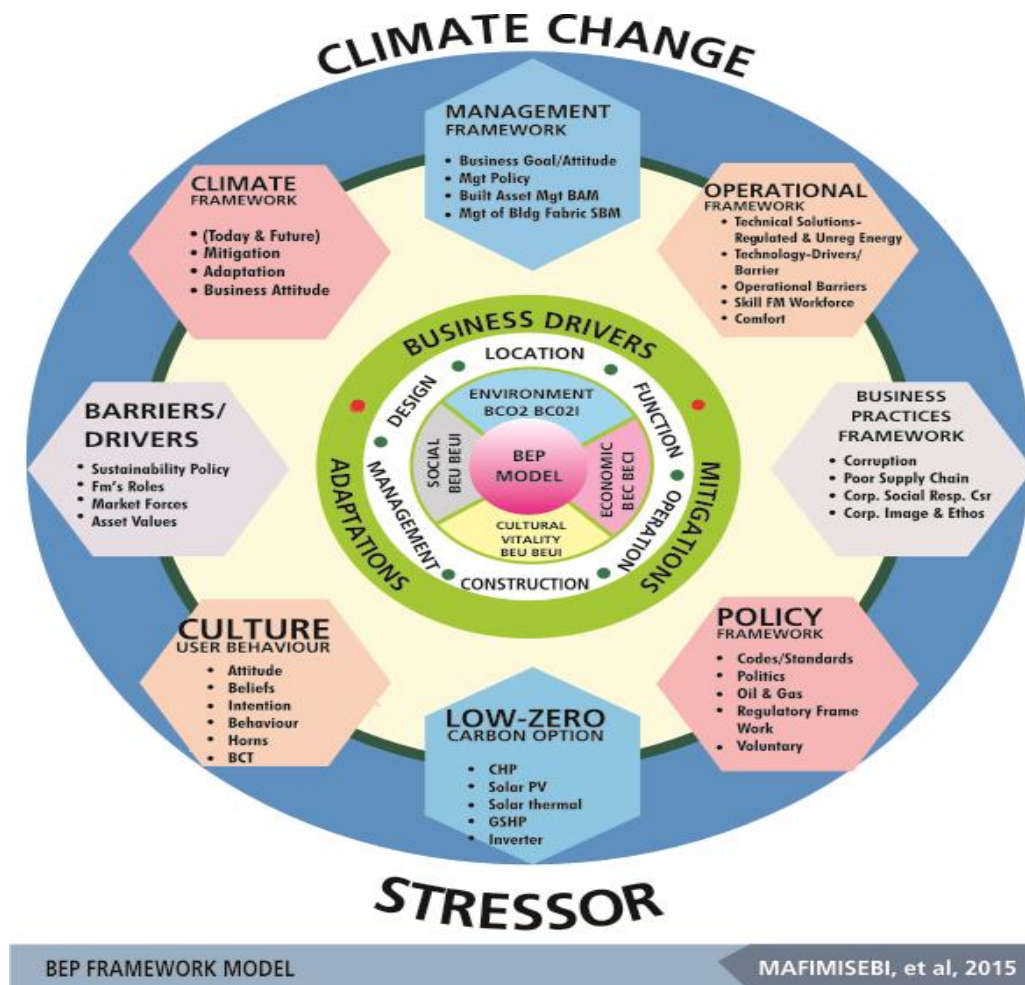


Figure 3.2: BEP Framework Model.

### 3.4.1 Climate

Climate directly affects BEU and BEP since extreme weather either heat wave or cold, affects heating or cooling requirement for buildings. It is expected that temperatures will increase in the next 50 years, and this will manifest in the form of lower comfort in buildings. The more extreme climate, atmospheric condition, the more energy required to power installed HVAC in maintaining the comfort requirement in buildings.



Previous studies (Gujba, Mulugetta and Azapagic, 2011; Wilkinson, 2012), have established CCH adaptation and mitigation measures as possible strategies for improving existing BEP. Therefore, the framework is underpinned by climate as amongst the reflexive indicators for improving EE of existing building lines. Herein, the model examined climate adaptation and mitigation measures undertaken by organisations as index for measuring the sustainability of BEP. The written and unwritten adaptation and mitigation policies are weighted based on Likert's scale. Thus, the concept 'climate' in the model represents a business attitude towards energy efficiency, conservation and carbon management focused building adaptation via adoption of mitigation policies (Vanags and Butane, 2013).

### 3.4.2 Management

The model envisages strategic building management (SBM) as central to SBM. Therefore, organisation's BEP sustainability based on management policy involves: built asset management (BAM) strategies; policy, business goals and attitudes; and management of building fabric. These variables are the indicators used to assess organisation's management intent; and are measured using survey questionnaire tools based on Likert's scale.

The management intents for CCH and BEP are in the form of: BAM, SSP, SFM and corporate image & ethos (CIEs), education & training on EE (ETEE), as CCH solutions gathered in this study. They are strategic and proactive policies that organisations could embrace to improve BEP and reduce CO<sub>2</sub> emissions in achieving sustainability. Each of the solutions is investigated for an organisation and intents measured in the form of written and unwritten policy based on Likert's scale.

Vanags and Butanes (Vanags and Butane, 2013), linked investment in strategic energy management and refurbishment with EE, conservation and carbon management principle in buildings. Thus, management index determines the level of sustainability and efficiency entrenched in organisations using studied buildings.

### 3.4.3 Operational

Likewise, building's operations have a direct influence on BEP. The operations and facilities within buildings need constant and consistent monitoring, auditing, maintenance and



management through operational FM to improve BEP. Current literature linked operational and technical interventions with sustainability and improved BEP (Altan, 2010; Tanneja, 2014). The better the monitoring and management of building operations, the more efficient it will perform in terms of EE.

The operational framework latent variables are identified and categorised as technical and operational solutions. The technical solution includes the following manifest variables: technologies embedment, envelope insulation, HVAC efficiency, LZC interventions, and regular maintenance/ energy retrofits. Whilst the manifest variables for operational solution involve: HVAC matching, use of energy model, efficient lighting/ equipment switching, regular energy audit, and regular assessment and benchmark. Also, questionnaire survey via the Likert's scale is applied to assess the constituent of each of these variables in an organization based on: written and unwritten policy, actual installation, and current practices.

The BEP is assessed based on the two underlying constructs (operational and technical solutions) for the operational framework in the BEP model. Whilst PMs and KPIs were used to measure the case BEU and evaluation of their BEP via NPI and EPL techniques.

#### 3.4.4 Barriers and drivers

Barriers and drivers could have either direct or indirect or both effects on BEU and BEP. They are intervening variables with an indirect impact on BEP. They could affect the management of a building and its operations. Current literature (Elmualim et al., 2010; Oyedepo, 2012), confirmed that barrier and driver have both direct and indirect impacts on BEU and BEP.

Fundamental to the barrier and driver context is decision-making. This involves the promotion of actions that propels BEU reduction and improves BEP (drivers), and rejection of actions that trigger inefficient consumption and poor performance (barriers) (Organ, 2015). The model enables policy makers (management) and operational FM to recognise these factors and be proactive through strategic planning for BAM.

Hence, identified barriers could have negative correlations, whilst drivers could result in positive correlations with other variables in the framework. The current study investigated these barriers and drivers to BEP based questionnaire survey via Likert's scale. They were

presented to FMs, owners and users who measured the perceived strength of each variable in their organisations in the context of the BEP model.

The identified barriers' manifest variables are: lack of policy, lack of energy codes and standards, lack of information on energy efficiency (EE), behaviour and lifestyle, poor supply chain, corruption, lack of technical skill, market force, asset value, political unrest and poor electricity supply. Whilst, the drivers' manifest variables are: combined SSP/SFM, SEM, renewable energy technologies (RETOs), PMs/KPIs, BCT, building energy management technologies (BEM Techs), and transparency & ethical business purchase (TEBP).

#### 3.4.5 Culture

Culture does have an indirect effect on EEP of commercial building stocks. Current study, established that cultural influences (based on users' norms, habitus, intention and behaviour), have indirect impact on BEE and CO<sub>2</sub> emissions via direct impact on BEU.

The culture index measured user's behaviour towards BEE and response to climate change amongst studied participants. The participants' habit, attitude, norms, intention, behaviour in relation to BEU; and the need for a behavioural change tool (BCT) were examined. BCT was further scrutinised under: information on EE, incentive programme, strategic change process, management advocate, POE, Energy audit, and monitoring and control of occupant behaviour (MCOB).

Past studies (Schelly et al., 2011; Lucon et al., 2014), have revealed that climate change awareness stimulate organisations to consider strategies to reduce BEU; and improve its EEP for economic and environmental reasons. Besides, these studies confirmed that behaviour, lifestyle and wellbeing of the occupants are all important drivers for BEU. Thus, consideration of culture, norms and users' behaviour is crucial during design, construction and operations of buildings.

#### 3.4.6 Business Practice

The activities of business within a building determine its energy utilization and the BEP. Hence, business practices are directly proportional to the volume or level of business activities engaged within the constructions. Furthermore, the issue of user's energy behaviour; and

appropriate BCT led to the investigation of how business practices affect BEP. Past studies (Okereke, 2007; Eberlein and Matten, 2009; Galbreath, 2011), confirmed that businesses now engaged in operational (internal and external) initiatives to reduce carbon footprint and address climate change.

Current framework considered a business practice as a possible factor that influences BEP. Although business practice is an extension of business culture but they were separated under the framework to differentiate between a user's behaviour, and corporate attitude towards BEP and the environment. The concepts of sharp practices, social corporate responsibility, and energy supply chain management were examined based on the research tool via Likert scale weighting. These variables were applied to investigate how corporate practices affect energy generations, supplies, BEU and BEP.

#### 3.4.7 Policy

Regulatory policy and incentivised measures have been successfully applied to mitigate against CCH and improve BEP globally. It is an intervention measure that bears a direct impact on BEU and BEP. Literature indicates that the UK and other developed nations have used climate regulatory policy to improve BEP and stabilised their GHGs (Andaloro et al., 2010; Dascalaki et al., 2012). Whereas, Nigeria needs such regulatory regime to reduce existing building stock CO<sub>2</sub> emissions and enhances their BEP.

Policy is associated with other framework contextual variables. It has been linked with CCH, building sustainability, business practice, operational and technical interventions in the current study. Thus, policy index is used to measure the impacts of regulatory framework, building energy codes, and energy certification on existing commercial BEP. The framework presented policy perception based Likert's Scale weighting, as an index for assessing the perceived impacts of policy on organisation's BEP. Though, policy indicators such as regulatory policy, institutional framework, codes and standards were also assessed through the barrier and driver index.

#### 3.4.8 Low-Zero Carbon

Low-zero carbon intervention has been substantiated to have an indirect impact on BEU, and a direct impact on carbon emissions and BEP. The use of solar PV panel in a building will not

necessarily reduce its energy use, but could reduce its CO<sub>2</sub> emissions. Some past studies (Bugaje, 2006; Olawuyi, 2013), have demonstrated the usefulness of low-zero carbon (LZC) interventions as the best methods of GHGs emission reduction, improves BEP, guaranteed energy access and security, and climate change mitigation. Thus, the installation of LZC technology in buildings is an intervention with direct impact, which could improve BEE but not necessarily reduce BEU.

The current study used the LZC index to measure perceived impacts of the installation of renewable energy sources. Herein, the model presented interventions such as: solar PV, solar thermal, micro wind turbine (MWT), inverter, ground source heat pump (GSHP), lighting/equipment efficiency (LEDs), combined heat and power (CHP), to participants. An increase in the use of LZC intervention, could increase energy supply, reduce GHGs emissions and mitigate against climate change. Consequently, the participants' opinion was explored in understanding the acceptance of renewable installation in the commercial buildings.

### 3.5 APPLICATION OF FRAMEWORK AS OPERATIONAL TOOLKIT

The identified variables impacting BEP are further translated into a checklist of factors in an excel spreadsheet. The variables are classified into constructs (latent) and respective reflective indicators, which are used as operational sustainability (OS) indices for assessment and benchmark. The OS toolkit (Appendix5), is applied in carrying out physical technical audit. Case buildings are assigned scores (-2 to +2) based on framework variables' weighting (Appendix7) associated with them.

Application of weighting in the technical assessment is based on the grouping of the OS toolkit factors into: organisation's policy, the organisation's practices, the government's policy, building's installations, behaviour (users and organisation) categorises (Appendix6). Buildings' scores are aggregated and categorised based on weighting. This allowed all case buildings to be categorised based on the BEP and sustainability current status quo. Whilst, the physical audit result formed the basis of initial OS assessment of case buildings. This is utilised to compare with indicators' statistically analysed data from quantitative and qualitative studies, and their BEU data based on PMs/KPIs.

### 3.6 SUMMARY

The overall research framework is presented, illustrating the study's eight contextual factors and their reflective indicators in the chapter. It explained the theoretical relationships between factors, and gave an overview of the framework. The study framework is built upon the contextual factors of operational, management, climate, regulatory policy, LZC interventions, culture, business practices and barriers/ drivers.

The chapter further expounds on the framework based on existing BAM model process; and the use of an OS toolkit of technical audit. The use of the framework for energy assessment and benchmark based on NPI and EPL, questionnaire surveys, interviews and application of OST are carefully explained. The methods of quantitative and qualitative data collections for operating the model are explained in the next chapter.

## 4 Chapter Four: Research Methodology

### 4.1 INTRODUCTION

This chapter presents the research methodology used in addressing the research objectives and questions. Study's planning started with a systematic, focused and well-thought-out purpose; philosophical assumptions were made and compared to other alternatives; alternative research designs were investigated and the reasoning behind the choice of multiple case study and case selection were tested; and strategies of inquiry were explored. The chapter, further, considered issues of reliability and validity; ethical concerns; and present the study methodology model, which outlined the protocol that fit the methods employed.

### 4.2 PHILOSOPHICAL ASSUMPTIONS

The current study philosophical approach is a pragmatic mixed method based on deductive logic. It used mixed method to identify the associations between the dependent factors, and independent factors, including intervening variables in the theoretical model. The theoretical model underpinned by prior theoretical knowledge illustrated in the previous chapter, served as guidance for current research methodology.

The study's approach harmonises with the view that theory can guide research (deductive approach), as against theory being the outcome of the research (inductive approach) (Bryman, 2012a). Hence, the study started with the idea generation, theory building, development of the model and the gathering of data to test the model (Bowling, 2002). Bryman (2012) referred to this approach as empiricism, expounding that it is a research conditioned by and directed towards the research questions, with the data collection, and analysis that focuses on the resolution of the research problems identified at the onslaught.

The concepts of deductive and inductive reasoning, and the differences between both are well documented in extant literatures (Bryman, 2008; Creswell, 2009a; Walliman, 2011; Creswell, 2013a). Deductive and inductive reasoning formed the fundamental of scientific reasoning and knowledge. Hence, the choice of method of investigation depends on the researcher's assumptions of the two phenomena (Walliman, 2011). The study adoption of deductive concept

is based on the premise that energy performance assessment is an underlying principle for BEP; and, the application of sustainability, management and operational interventions for propelling BEP. It is different from the inductive method that involves starting with collection of data and building up observations for testing them (Bowling, 2002).

The work of Saunders et al (Lewis, 2012), indicated in Table 4:1 below helped explains the difference between deductivism and inductivism. This is necessary as current study is unpinned by deductive logic.

Table 4:1: Difference between Deductive and Inductive Approaches.

Differences between Deductive and Inductive Approaches	
Deductive	Inductive
Based on scientific principles	Seek to gain understanding of the meaning of human events
Moves from theory to data	Move form data to theory
Concepts are operationalised to ensure clear definitions are defined within the research	Research structure is flexible, allowing adoptions as the research progresses
Very structured approach; researcher is independent of the topic being researched	Researcher is part of the research process
Appropriate sample size is needed to generalise conclusions	Generalised results are less import
Quantitative data collection	Qualitative data collection

Adapted from (Saunders et al., 2007; Lewis, 2013).

It is understood that the strength of current research is built on, investigating how selected case-study buildings perform against predetermined EE theory in the real world. Hence, these buildings are studied the way they exist in the real world, and the researcher was independent of the investigation. The drawback is that they are limited to little controls, unlike laboratory research where controls are limitless. Nevertheless, the multiple case study approach was taken to overcome this drawback, to reduce variability and improve reliability.

The adopted research “assumptions relate to the nature of reality (the ontology) and the extent to which this reality can be known (the epistemology)” (Organ, 2015). However, philosophical assumptions, ontologies, epistemologies and methodologies have been grouped into a research paradigm (Creswell, 2009; Organ, 2015).

Numerous studies have expounded on research paradigms. A paradigm is a theoretical framework that includes a system by which people view or mirror an event. The operation of paradigms helps to operate not only what views are accepted, but also the determination of approach to questioning and discovery (Fellows, 2008). Organ (2015), extended the idea as, she likened it to orientating thinking and research. Taking it further, Creswell (2009) clarified that a paradigm is shaped by the discipline of the researcher and past research experience. He opined that the types of beliefs held by the researcher determine the type of research strategy he will engage, and that there are four types of paradigms or worldviews namely, post-positivism, constructivism, advocacy/ participatory, and pragmatism.

Knight et al., (2009), further explained that understanding the influences that competing paradigms have on the way we carry out researches is fundamental to understanding the contribution that it makes to knowledge. They believed that, different research paradigms will inevitably result in the generation of different kinds of knowledge about the industry and organisation. Therefore, the choice of paradigm adopt will fundamentally affect the ways in which data are collected and analysed, and the nature of the knowledge produced.

#### 4.3 ONTOLOGY

Objectivity and Constructivism (Subjectivity) are two ontological orientations in opposite continuum in the world of scientific research. May (2011) expounds that objectivity, generalisation, and explanation are fundamental characteristics of science, and it refers to our world out there. Objectivity is about carrying out a study that is independent of our opinions and prejudices, that help substantiate, refutes, organises, or generates theories and produce evidence that challenges our personal beliefs and that of the society.

Subjectivity refers to people's thinking, and 'our inner world experiences, rather than the world out there'. Subjectivity focuses on the meaning people gives to their environment, not the environment itself, which is the understanding and interpretation they have on their environment (May, 2011).

The current study adopted both objective and subjective approaches for generating and analysing data based on study model. It employed both explanatory and exploratory based



studies. The study developed indicators to measure case buildings BEU and BEP; and model variables to emphasise the relationships between, policy interventions, barriers and driver factors, sustainability, facilities management, climate and BEP. It also investigated users' use behaviour; thus, justifying the use of objectivism and positivism approach. It used interview to investigate owners and facilities manager's perception of model contextual variables. It helps obtain the peoples' perception of varied factors and model variables, which also justify the use of subjectivism and constructivism.

#### 4.4 EPISTEMOLOGY

Positivism and interpretivism are two opposite epistemological divides that are associated with objectivity and subjectivity respectively. Positivity is a quantitative approach based on deductive testing of theory using the natural science model, while interpretivism is predicated on the inductive generation of theory using a qualitative approach (Creswell, 2009a).

Creswell (2009), linked four principles to positivism, which entails: science must be conducted in an objective manner that is value free (objective); only experience and hence knowledge confirm by the senses can be regarded as true knowledge (Phenomenalism); and the purpose of theory is to generate propositions for testing and allows law to be assessed (deductivism). Furthermore, knowledge is established through the gathering of facts that provide the basis for laws (inductivism), and there is difference between scientific statements and normative statements (Ibid).

Fellow and Liu (2008) believed that, observable and measurable facts should involve processing of observation and measurement that is uninfluenced by the observer. Including that, positivism recognises only non-mental physical facts and observable situation, which make it closely related to rationalism, empiricism, and objectivity.

The positivist paradigm comes from the 19<sup>th</sup> century writers such as Comte, Mill, Durkheim, Newton, and Locke (Creswell, 2013b), and others like Phillips. The problems studied by positivists often require a need to examine the causes that influences outcomes. It is also a reductionist idea as the intention is to reduce the ideas into a small discrete set of ideas for testing. Including the knowledge based on careful observation and measurement of the reality that exists in the world objectively (Ibid).

Interpretivism is a contrasting epistemology to positivism. It is predicated on the view that a strategy is required that respects the difference between human beings and the objects of the natural world. This, Creswell (2009) argued, requires social scientists to understand the subjective meaning of social action. Reality is a social action constructed by the person involved. The person's reality as claimed by Fellow and Liu (2009) is derived from observations and perceptions and modified by socialisation may be different from another's.

Creswell (Creswell, 2013a), further expounds that the truth and reality are social constructs, rather than existing independent world out there. Therefore, researchers must be determined to know the truth and reality from participants' collective view. Interpretivism is about the understanding of human behaviour with emphasis on human action rather than the forces are deemed to act on it. In Creswell's view, it is an interpretive understanding of social action rather than the forces that are external to it. It involves taking causal explanations regarding the interpretative understanding of social actions. Interpretivism is often used in qualitative than in quantitative studies.

Knight et al., (Knight, 2009), tried to differentiate researchers in the built environment using the diversity of methods they employ. This includes those that embraced the objective engineering orientation, where the focal point is on discovering something factual about the world, it focuses on, with an emphasis on causality and generalizability; and those that adopted a subjectivist approach, where the aim is to see how different realities are made up with emphasis on localised subjective meaning. Here current work draws upon the strength of both approaches.

The appropriate knowledge of this research is therefore, the epistemological position of both positivism and interpretivism, which follows the principles, procedures, and ethos of research of the natural science (Bryman, 2008); and that of individual person's reality as claimed by Fellow and Liu (2009) derived from observations, perceptions and modified by socialisation. Positivism though the dominate philosophy underlying quantitative scientific method, needed to be complemented with interpretivism for cross validation of this research data set. Therefore, both were adopted in a multiple-case study approach for this study.

Making a knowledge claim about a research, means that, the researcher starts the study with certain assumptions about how learning will be acquired, and what will be learned during the inquiry (Creswell, 2013b). The idea is that, the world of BEP out there is independent of our interpretation (positivism and empiricism). Thus, the need for both exploratory and explanatory cases-study based on selected buildings, which could help determine factors that influence BEP in Nigeria compared to the UK.

#### 4.5 RESEARCH DESIGN

The present study used the case study method based on a multiple-case approach as its research design. Some studies (Yin, 2009; Simons, 2012; Yin, 2014), have confirmed that the use of case study method could incorporate the mixture of both quantitative and qualitative data. Hence, the present study adopted a mixed method of data collection and analysis within a multiple case study approach.

The choice of the case study method was based on the consideration that: the BEP of study's buildings and its influencing variables are contemporary not historical phenomenon; the researcher has no influence on participant's behaviours; and that the research questions are about "what" and "how", as a foundation for study's informed decision (Yin, 2009).

The concept of BEE is a phenomenon, in which its independent factors were considered alongside several contextual variables. Here, holism is assumed to be more than the sum of the endogenous factors that affect BEP; and that these BEP factors should be examined in their entirety alongside consideration for those contemporary variables that are exogenous to BEP (Thomas, 2016). This reinforced the emphasis on the underpinning meaning ascribed to case study by several studies (Yin, 2009; Simons, 2012; Yin, 2014; Thomas, 2016). Thomas (2016) sees it as meaning "*that certain phenomena are more than the sums of their parts, they must be understood as a whole, rather than a subset of interrelated variables*" (p47).

Whilst, Simons (2012) argued that case study is "*an in-depth exploration from multiple perspectives of the complexity and uniqueness of a project, policy, institution, programme or system in a real-life context*" (p21).

Yin (2009, p18; 2014), also, described case study research as “*an all-encompassing method involving logic of design, data collection techniques, and specific approaches to data analysis based on two-fold technical definition*”. Yin, referred to the two technical definitions of case study as:

*“A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context; especially when the boundary between the phenomenon and the context are not clearly defined”*; and

*“A case study involves a unique technical circumstance in which there exist more variables of interest than data points, thus researcher depend on multiple sources of evidence, and benefit from the prior development of theoretical propositions to guide data collection and analysis”*.

These definitions informed the perspective of current research method. The aim is to answer research questions based on the developed holistic model for assessing BEP across cases; and in comparing Nigeria to the UK. Herein, the BEP is viewed from holistic perspectives (both impacting factors and contextual variables) within a system (the organisation) in the real-world context. The definitions also help the study to illustrate how the questions were tackled, and the all-encompassing methods deployed based on the model to achieve the research aim.

Herein, the investigation into case buildings’ BEU data in ascertaining its BEPs, cannot be distinguished from various contextual variables (location, operations, management etc.). Also, the study’s phenomenon involves several contexts that could not be controlled by the researcher, unlike laboratory experiment with few variables that are controlled (Yin, 2009; Yin, 2014). Hence, the appropriateness of the case-study method based on both exploratory and explanatory cases-studies approach to this study.

An ‘all-inclusive’ and ‘pluralistic’ approach of research method was used for the exploratory and explanatory purposes. Study’s investigations were performed through survey, archival analysis, and case study research methods based on its research questions (Yin, 2009; Yin, 2014). Thomas (2016), stressed the importance of the research question in a study. He argued that the research question is the “*starting point and pivot of research, and that everything rest on it*” (p29). Thus, study questions are defined and categorised (*Table 4:2* below), to ascertain their constituent and focus on fundamentally critical issues in this study.

Table 4:2: Research Questions and Methods Used.

SN	Research Questions	Research Method Used	Requires Control of Behavioural Events?	Focuses on Contemporary Event?	Focuses on Phenomenon?
1	What are the critical factors influencing BEEP?	Survey, Case study, & Archival	No	Yes	Yes
2	What are the relationships and interdependencies between these independent factors and the EE of existing buildings in both countries?	Survey, Case study, & Archival	No	Yes	Yes
3	How could PMs and KPIs be identify and develop as a range of energy performance metrics and KPIs; and be integrated into new model based on multiple-case study method?	Survey, Case study, & Archival	No	Yes	Yes
4	What are the drivers and barriers that influence the effectiveness of the independent factors to affect EE of existing buildings?	Survey, & Case study	No	Yes	No
5	In what way can SP and FM drives the low carbon goal in existing buildings?	Survey, & Case study	No	Yes	No
6	How will study theoretical framework be translated into an integrated application for EE planning and operational based BEP management model?	Survey, & Case study	No	Yes	No

Research Questions and Methods used: adapted from Cosmos Corporation, (Yin, 2009).

The current study encompasses both the ‘how’ and ‘what’ form of research question as detailed in *Table 4:2*. The strength and weakness of using a case study method as exemplified in extant literature (Simons, 2012; Yin, 2014; Thomas, 2016), formed the basis of study. Drawn upon these past studies, current study’s adoption of case study has the following advantages compared to other methods:

- I. It is good for studies that cover the phenomenon of interest and its context resulting in large variations; and
- II. It allows for replication logic that give stronger validity and reliability.

Case studies, nevertheless, are not appropriate for the application of sampling logic used in surveys, as they are not the finest method for assessing prevalence or frequency of a phenomenon (Yin, 2014).

#### 4.5.1 Multiple Case Study

Multiple case study design is adopted by the current study for comparisons between heterogeneous office’s buildings in Nigeria compared to the UK. Past studies (Yin, 2009; Yin,

2014; Thomas, 2016), have shown that a multiple-case study is considered better than a single-case (classic-case) study approach for comparative studies.

Multiple case study approach was used to examine the energy use and the BEP of five selected buildings in Lagos Nigeria, and five selected buildings in Chelmsford UK. The approach was deemed suitable for this aspect of the study as in-depth knowledge is required to investigate and evaluate the concept of BEP amongst these buildings.

Yin (2014), asserts that multiple-case studies are often considered a more compelling and more robust overall study than a single-case study. This is because of its use of multiple sources of evidence and established chain of evidence. It also has the advantage of replication logic by succeeding to replicate findings through conducting more than one study. The reason is that selected cases should be able to predict the same result (literal replication) or predict divergent results for a theoretical application. Nevertheless, multiple-case study has been criticised for time and extensive resources required, having often more than what single student can meet (Yin, 2014; Thomas, 2016).

Another rationale for adopting a multiple-case method is that the current study tackled case buildings in Nigeria and UK as two separate multiple-holistic cases. The cases within each location were treated as multiple-embedded cases (Yin, 2014). This helped account for the variance in the heterogeneous nature of the study. Also, the choice of multiple holistic-approaches (within a country) and embedded-approach (in separate countries) for cases ensure theoretical replication (Simons, 2012; Yin, 2014).

The present study adopts the protocol for a replication approach to multiple-case studies as outlined by Yin (Yin, 2009; Yin, 2014). Herein, based on the theoretical model developed from the study's literature, case buildings were selected using selection criteria (*Table 4:3*), and procedures in the next section.

#### 4.5.2 Case Selection

The selection process for cases was based on precise reasons why the ten buildings were needed. The purpose of this is to form a sampling frame for the study, thus, the process involved setting criteria upon which the cases are qualified (Organ, 2015). The selection process was

based on BEP indicators and contextual variables, their unit of measurement, the linking of data to research questions and criteria for interpreting the findings (Yin, 2014).

Critical issues of access to data, and satisfying rigour and robust investigation were also considered as criteria in selecting the case buildings. Additionally, validity and reliability based on the principle of succeeding repetition were a consideration (Yin, 2009; Thomas, 2016). Hence, in satisfying the requirement for replication logic, case buildings were selected based on: climate zone (location), building size, and year of construction including energy consumption, operational sustainability, and building's use. The user's profile was further broken down into: office use only, office/ domestic use, office/worship, office/ school, office/ sport centre and office/ commercial (Table 4:3).

The selected users' profile represents the dominant types of commercial buildings in both cities and more especially Lagos, Nigeria. The case buildings' operational sustainability criteria were further categorised into low, medium and high levels.



Table 4:3: Study's Case Selection Criteria

Case Selection Criteria			
SN	Criteria	Justification	Sources
1	Data Access	Study literature has confirmed that lack of access to data could hinder case study research or lead to change of research questions. Hence, only approved case buildings with access to data by owners were selected.	Akande, O., 2015; Organ, 2015; Chung, 2011; Chung, Hui and Lam, 2006; Bordass, B., and Leaman, A., 2005; Bordass et al., 2001; etc.
2	Climate Zone Location	Climatic location of a building determines its BEP as the literature suggested. Therefore, location plays an important factor for a comparative case study that involve two countries in different climate zones.	Li, Hong and Yan, 2014; Nicholls, C., 2014; Chung, 2011; Ole Fanger, 2006; Chung, Hui and Lam, 2006; Ward, 2004; etc.
3	Building Type	BEU and its BEP depends on the type of building, as indicated in the literature. This will definitely have some impacts on its BEP.	Organ, 2015; Li, Hong and Yan, 2014; CIBSE, 2008; CIBSE, 2006; Ole Fanger, 2006; etc.
4	Building Use	Literature has suggested that the use of a building has impacted on BEU and BEP. The study tries to examine the effect of building use on its BEP.	Li, Hong and Yan, 2014; Lovisa, 2014; Ifigenia, 2013; Lewis, 2012; CIBSE, 2008; CIBSE, 2006; etc.
5	Building Size	Also, current literature suggests that the size of the building has an effect on its BEU and BEP. Hence the need to determine potential impact of this on BEP.	Li, Hong and Yan, 2014; Lovisa, 2014; Ifigenia, 2013; Lewis, 2012; CIBSE, 2008; CIBSE, 2006; etc.
6	Year of Construction	Literature suggests that different years represent different enactments of BEU and BEP regulatory policy. Hence, different codes for envelop and service efficiency. Therefore, selection criteria use this to ascertain the effect of regulation on BEP	Akande, O., 2015; Organ, 2015; Lovisa, 2014; Ifigenia, 2013; Lewis, 2012; CIBSE, 2008; CIBSE, 2006; etc.
7	Operational Sustainability	The sustainable level at which a building is being operated has shown to affect its BEP. Therefore, criteria for engagement of SP and FM becomes a consideration in case selection.	Li, Hong and Yan, 2014; Lovisa, 2014; Ifigenia, 2013; Lewis, 2012; Jones and Sharp, 2007; Ole Fanger, 2006; etc.
8	Energy Used Data	The importance of access to building's energy bill data for the study period has been reiterated in the literature. Hence, only buildings with the complete data set from 2011-2014 were selected.	Lovisa, 2014; Ifigenia, 2013; Lewis, 2012; Chung, 2011; CIBSE, 2008; CIBSE, 2006; Ole Fanger, 2006; Chung, Hui and Lam, 2006; etc.
9	Energy Source	The literature suggested that different energy source, especially diesel-based generations are a result of poor energy supply infrastructure, and poor supply chain. This could lead to lower EE performance.	Lovisa, 2014; Ifigenia, 2013; Lewis, 2012; CIBSE, 2008; CIBSE, 2006; etc.
10	Occupancy	Occupancy hour is an important factor for BEE as indicated in studying literature. Therefore, selection criteria were based on cases with hour occupancy.	Organ, 2015; Li, Hong and Yan, 2014; Lovisa, 2014; Ifigenia, 2013; Lewis, 2012; CIBSE, 2008; CIBSE, 2006; Ole Fanger, 2006; etc.

The current study acknowledges the differences in the independent variables for these comparable cases. Hence, the study model was developed as a common basis for testing its sensitivity to varying parameters of the context (Swanborn, 2010). The table outlined the conditions against which potential case study buildings were examined and chosen.

#### 4.5.3 Justification for the selected Study Locations

Availability of buildings in the same location and access to their energy data set (four-year data set), based on purposeful sampling technique were used as a selection of Lagos and Chelmsford



as locations in both countries. The approval by owners for the use of these buildings in the research study and disclosure willingness by reporting CSR (Idowu and Towler, 2004), are critical success factors that could improve BEP. This selection method aligned with the view of Fellow and Liu (2008), that case study can be used to demonstrate facets of a research topic base on statistical sampling.

Environmental Management Policy or Quality Management System in building management of organisations, were also applied to select office buildings in addition to the study case selection criteria (*Table 4:3*). Consideration was given to the Owners or the organisations evidence (the uptake) of environmental management system (ISO 14001), EN16001 standards and energy management system (ISO 15001; 2011) (Rudberg, Waldemarsson and Lidestam, 2013).

This aided the assurance of sustainability and energy analysis of the selected buildings (Egwunatum, Joseph-Akwara and Akwaige, 2017). The TEFMA (2014), also made a case for standardized management and reporting for university facilities based on management system and certification (ISO 14001- Environmental Management System; ISO 9000- Quality Management System; and AS48001- Occupational Health & Safety Management System) in addition to the Global Reporting Initiative- GRI Accountability & Reporting Standards.

Five case buildings were selected from each country instead of one in ensuring rigor and robust based on adequacy and appropriateness. Maha Shakir (2002), argued for evidence based on adequacy and appropriateness, which is often considered more valid, as selection of cases driven by the two concepts improve the quality of multi-case research design. The current study satisfied the criteria for appropriateness by the selection of cases that demonstrated a fit for the research and phenomenon of inquiry. While adequacy of ten cases instead of one based on, how many cases is required satisfied the need for attending at a different typology of office buildings (Ibid). This aided the inclusion of cases (heterogeneous) that might not conform to the requirement of sustainable management.

#### 4.5.4 Justification for selecting Nigeria and UK

The selection of UK as the country to benchmark with Nigeria was based on the criteria that the UK is the recognised as the first country to produce an environmental assessment tool for

office Buildings known as BREEAM in 1990 (Sharifi and Murayama, 2014; Bonham-Carter 2010). The building sustainability measurement and independent certification tool laid the foundation for building environmental performance. Also, BREEAM contained energy efficiency criteria that were in use before the establishment of the EU EPBD 2002 (EPBD 2002/91/EC); and it helped revolutionize assessment and benchmark of buildings' energy performance globally.

Nigeria was chosen amongst other SSA countries due to its population as the largest in Africa; and the country with South Africa have the largest share of more than 45% of the regional energy demand rise between 2002 and 2012 (IEA, 2014b). Whilst, SS already has building energy code since 2011 (UN-HABITAT, 2011), Nigeria is yet to accomplish this, hence, her choice is significantly aligned with the study aim.

#### 4.6 STRATEGY OF INQUIRY

Strategies of inquiry provide specific direction for procedures in a research design and contribute to its approach (Creswell, 2013b). It involves the choice of adoption of either quantitative, or qualitative, or mixed methods research strategies. The choice to adopt one or the other strategy must be made along with other keen tactical decisions. This in Bryman's view (Bryman, 2008; Bryman, 2009; Bryman, 2012b), is about the tactic in which the research will be carried out and the data analysed. This tact also depends on the choice of research design and research method.

The current research engaged the mixed method's strategy, based on, explanatory sequential design (Creswell, 2015), within multiple-case study approach. This is known as mixed method multiple-case design, "which is intercepted by mixing methods within the case study approach" (Clark and Vicki, 2016) (p147). The study incorporates quantitative and qualitative techniques, methods, approaches, concepts in a multiple-case study into an integrated node (Yin, 2014).

The strategy has the advantage of using multiple paradigms to understand BEP and its context in the real world. It gives a clearer illustration of the research macro contexts, and help to examine the theoretical relevance from the respondent's perspective. Nevertheless, the only drawback to the strategy was the difficulty of using quantitative method to provide useful

information from a small sample size (Clark and Vicki, 2016). However, the use of multiple data sources and replication logic for multiple cases helped overcome this drawback.

The advantages of using mixed methods over quantitative or qualitative are well documented in existing literatures (Fellows, 2008; Bowling, 2009; Creswell, 2009a; Bryman, 2012b; Creswell, 2013a) etc. Bryman, (2009) further explained that the mixed methods research is the combination of at least one qualitative and at least one quantitative component in a single research project. This is because it has both advantages of the quantitative and qualitative methods when use on a non-human subject (multiple-case BEU and BEP), and human subjects for data collection and analysis.

The study's strategy allows for more insight to be gained from the combination of both qualitative and quantitative researches than using the mono - method. Hence, mixed method provides an expanded understanding of current research questions. It also has the advantages of utilizing the strength of both qualitative and qualitative research (Creswell, 2009b).

The current study is complex in diversity and magnitude, as it involves multiple data sources. Thus, the use of mono research methods is inadequate to address its complexity (Creswell, 2009b). Also, BEP phenomenon and its contextual variables required interdisciplinary nature of inquiry, diverse methodologies and approaches. This could only be achieved via the mixed methods, multiple-case approach adopted.

Despite the fabulous advantages of using mixed methods, however, it comes with its own constraints. Which are time intensive nature, there is usually a longer time needed for the researcher to collect and analyse both text and numerical data; and it involves researcher to acquire the skills and knowledge of both qualitative and quantitative research methods (Creswell, 2009b).

Several studies (Baker, 1999; Fellows, 2008; Knight, 2009; Robson, 2011), have expounded on strategy for qualitative and quantitative methods including the differences between them. Current study's quantitative strategy involves survey of empirical data on BEU and BEP assessment for case buildings; and questionnaire surveys on model contextual variables. The strategy ensured that measurement and quantification were central, and adherence to the scientific approach, reliability and validity were achieved.

It provided detailed specification of procedures for replication, data analysis, generalisation of findings, objectivity, and standardisation for control and accuracy (Robson, 2011). The current study does seek human interpretation of themes based on developed research model, which make it suitable as a method for cross validation (Baker, 1999).

The choice of mixed methods, multiple-case study is informed by the phenomenon and contextual circumstance of study. The study involved gathering dataset that were both objectively and subjectively collected, analysed and interpreted. This is important in establishing validity, generalisation, reliability, and replication of results. It also looked at users' behavioural aspect of BEU, and human interventions like SP and FM roles as drivers for BEP. Finally, the research used congregated data to explain the relationship between model factors, contextual variables and BEU acquire to deeper understanding of BEP.

#### 4.7 ENERGY PERFORMANCE INDICES CALCULATION METHODOLOGY

The concept of EE and its operationalisation has been explained in study literature (Patterson, 1996). EE in buildings has been strongly linked to improved building performance; energy savings and CO<sub>2</sub> emission reduction; and is built upon the principle of using less energy for heating, cooling and lighting without affecting the health and comfort of occupants (Nikolaou, Kolokotsa and Stavrakakis, 2011b).

Extant literatures (Ebohon and Ikeme, 2006; Chung, Hui and Lam, 2006; CIBSE, 2006b, etc.), also promote the use of energy performance indices (EPIs) as methodologies for energy benchmarking, rating and classification of building EEP (BEP). These EPIs are: BEU (energy used in kWh); BEUI (BEU intensity measured in kWh/m<sup>2</sup>); and Carbon intensity (CO<sub>2</sub>I calculated in kgCO<sub>2</sub> emissions/m<sup>2</sup>). They are indices that define the energy and environmental performance of case-study buildings and allow for comparison between them (CIBSE, 2006b). The indices represent the energy, environmental and economic performance of buildings in the study's model.

#### 4.7.1 PMs and KPIs Calculation

The present study, therefore, used BEU, BEUI, BCO<sub>2</sub> emissions, BCO<sub>2</sub>I, BEC (building energy Cost), and BECI (building energy cost intensity) as methodologies for energy assessing and comparing case BEP in both countries. Herein, BEE is the dependent variable, while PMs (BEU, BCO<sub>2</sub> emissions, and BEC), and KPIs (BEUI, BECI and BCO<sub>2</sub>I) are the independent variables. The PMs and KPIs are the endogenous factors that influences BEP, whilst model variables are the exogenous factors (contextual) to BEP.

Existing studies (Ebohon and Ikeme, 2006; CIBSE, 2006b), confirmed the association between: climate and BEU; fuel type, and BEU/ CO<sub>2</sub> emissions; energy access and energy intensity/ CO<sub>2</sub> emissions etc. Some prepositions of these assumed that: energy intensity and CO<sub>2</sub> emissions are fuel type dependent; energy access influences rate of energy intensity and CO<sub>2</sub> emissions (Ebohon and Ikeme, 2006); and energy used is directly proportional variation in weather (CIBSE, 2006b), are well considered in the present study.

The aggregate BEU, BEC and CO<sub>2</sub> emission values of case buildings are, thus, normalised by thermal comfort parameter (gross floor area, occupancy, and cooling / heating degree days) to account for variations in these parameters and sets of indicators (Batagorawa, Hamza and Dudek, 2011). Climate adjustment for case BEU in both countries is performed by the application of degree-day normalisation (Chung, Hui and Lam, 2006; Chung, 2011). Further, the economic adjustment is achieved by the application of the current Central Bank of Nigeria (CBN) forex official exchange rate. The CO<sub>2</sub> emission is normalised with the application of carbon emission factors for both countries (Matthew et al., 2011).

The indicators (BEU, BEUI, BCO<sub>2</sub> emissions, BCO<sub>2</sub>I, BEC, and BECI) were used to measure cross-country variances EEP of case study buildings (Patterson, 1996; Chung, Hui and Lam, 2006; Olofsson, Andersson and Sjögren, 2009) etc. The calculation methodologies for these six indicators (PMs and KPIs) are presented beneath.

The three energy PMs used in assessment of case buildings are as follows:

- I. BEU is the total energy consumption per annual for each case building.

$$\text{Thus: } BEU = \text{monthly}(BEU) \times 12 \text{ months} \dots \dots \dots \text{Equation 1}$$

- II. BEC is the total cost of BEU per annual, which is the cost of grid electricity tariff plus diesel/ PMS fuel used by fossil-fuel generators (equation2).

$$BEC = \text{monthlycost}(\text{grid electricity} + \text{used fuel}) \times 12 \text{ months} \dots \dots \dots \text{Equation2}$$

- III. CO<sub>2</sub> emission is derived from the total BEU by energy source. The fossil-thermal fuel quantity is multiplied by the calorific value of energy source-type to arrive at the kWh value (Matthew et al., 2011; Iain, 2011; ACEA, 2015). The following assumptions were made in obtaining the case BEU, BCO<sub>2</sub> emissions and BEC.

Assumptions:

- a. Average unit cost of electricity (₦/kWh) in Lagos, Nigeria based on Bldg104 meter reading are: 2012 (₦15.79/kWh); 2013 (₦18.40/kWh); 2014 (₦18.27/kWh); and 2015 (₦22.64/kWh).
- b. The unit cost of grid-electricity (£0.13/ kWh), and gas-electricity (£0.04/ kWh) were based on Anglia Ruskin University energy bills supplied by Estates and FM dept.
- c. Arup office building's electricity consumption was based on PHCN estimated bills as charges to Arup. The unit of electricity consumed is calculated based on estimated bills cost divide by the average unit cost of grid electricity supplied for each respective year as stated above.
- d. Calorific value of diesel fuel is 45.5MJ/kg (36.9MJ/litre), and petrol is 45.8MJ/kg (33.7MJ/litre) (ACEA, 2015);
- e. 1kWh = 3.6 MJ, therefore, 1litre of diesel contains 36.9MJ/3.6MJ (10.25kWh), and 1 litre of petrol contains 33.7MJ/3.6MJ (9.36kWh) (Iain, 2011);
- f. 1kg (1.202Litres) of diesel produces 2.65kgCO<sub>2</sub>, therefore, 1litre of diesel produces 2.20kgCO<sub>2</sub>e; and 1kg (1.361Litres) of petrol produces 2.30kgCO<sub>2</sub>, therefore, 1 litre of petrol will produce 1.69kgCO<sub>2</sub>e (ACEA, 2015).

Carbon emission factors (C<sub>f</sub>) of 0.509CO<sub>2</sub>/kWh for grid electricity; and 0.184kgCO<sub>2</sub>/kWh for gas-electricity as fossil-thermal source (Matthew et al., 2011), were applied to obtain case building CO<sub>2</sub> emissions (shown eq.4 below). Thus:

$$CO_2 \text{ emissions} = \text{monthly}(\text{grid electricity} (kWh) + [\text{fuel}(\text{litre}) \times \text{calorific value}]) \dots \dots \text{Equation3}$$

Therefore:

$$CO_2emissions/annual \equiv monthly(\{electricity(kWh) \times C_f\} + [Fuel(litre \times kWh) \times C_f]) \times 12months$$

..... Equation4

Whilst, the three energy KPIs for the case buildings were calculated as follows:

- I. BEUI, also known as the normalised performance index (NPI), is building energy (electrical and fossil-thermal) consumed divided by the building gross floor area (CIBSE, 2006b), given as:

$$BEUI = yearly\left(\frac{kWh}{m^2}\right).....Equation5$$

- II. CO<sub>2</sub>I is the emission density expressed in kgCO<sub>2</sub> emissions per gross floor area (GFA) per annual for case buildings (eq.6 below):

$$BCO_2I = yearly\left(\frac{kgCO_2}{m^2}\right)..... Equation6$$

- III. BECI is the energy cost density expressed as the BEU cost (eq.2) per GFA for case building (eq.7 below):

$$BECI = yearly\left(\frac{EC(£)}{m^2}\right)..... Equation7$$

#### 4.7.2 Normalisation Factors

The degree-day (DD) or accumulated temperature difference (ATD) is used for normalisation for benchmarking cross-country case buildings. It is underpinned by the fact that in the UK, indoor temperature of an unheated building is higher than the outdoor temperature (McMullan, 2012). Whilst, in Nigeria, the indoor temperature of uncooled building is lower than the outdoor temperature. UK's buildings' indoor temperature difference is taken at 3°C, however, that of Nigeria is relatively unknown. The current study used DD to assess and analyse case buildings energy consumption data based on the study model (CIBSE, 2006a).

Al-Shemmeri (2011), explained that DD indicates how far in a month, the outside temperature is above the base temperature. The base temperature is used as a reference for counting the either temperature drops or ascents, and the number of days for such drops or ascents in a year (McMullan, 2012). It helps provide a climate correction for energy consumption over long time periods.

The drawback to the use of degree-day is that it does not account for “solar radiation, prevailing wind and local outdoor temperature profile of the building” (Al-Shemmeri, 2011) (p33). The cooling degree-day (CDD) is used for buildings in Lagos, while heating degree-day (HDD) is used for cases in Chelmsford.

The degree-day calculation (Szokolay, 2014), is:

$$DD = \sum (T_b - T_{av})(365 \text{ days}) \dots \dots \dots \text{Equation 8}$$

Where  $T_b$  is the base temperature; and  $T_{av}$  is the average temperature of the daytime.

The benchmarking of case buildings in Nigeria and UK is performed based on the CIBSE TM46 guide for standardised conditions of weather and occupancy. The weather year for Chelmsford (UK), is standardised at average 2100HDD (Szokolay, 2014), °C per year with a base temperature of 15.5°C (Mario, 2014). Whilst, Lagos, is standardised at average 2653CDD/year (Sivak, 2009), with a base temperature of 20°C (Ogunsote and Prucnal-Ogunsote, 2010). The case buildings’ BEU data are adjusted based on the factor (ratio) of average DD for each country and the actual DD that occurred within 12-month energy consumption record period (CIBSE, 2006a), as thus:

$$NPI = BEUI \times \left( \frac{\text{average DD}}{\text{actual DD}} \right) \dots \dots \dots \text{Equation 9}$$

#### 4.7.3 Case Buildings’ Energy Performance Lines

A study (CIBSE, 2006a p1), confirmed that “the energy consumption of a heated or cooled building over a period is proportional to the sum of temperature differences over this period”. This is the underpinning theory of the used of energy performance line (EPL) for the assessment and comparison of EE of study case buildings. A linear model using the least square regression method is used to fix a performance line of best fit in this study. The performance line is a line of best-fit plotted through BEU and DDs data. It is an energy management tool



that indicates how BEU varies with the weather; and a dependable indication of building's response via sizeable data (CIBSE, 2006a).

CIBSE (2006a), elucidate that it implied that when all other factors (base loads, etc.) are kept constant, BEU (for heating or cooling), is directly proportional to changes in outdoor temperature. Thus, when a graph of BEU is plotted against DDs to a base temperature, it gives a straight-line graph based on a linear equation model (equation10):

$$y = C + Mx \text{ .....Equation10}$$

Where, y is the building energy consumption (BEU); x is the CDDs or HDDs; C is the y-axis intercept, which represent the base load energy; and M is the slope of the line. The linear model based on least square could be used to predict the energy consumption of case buildings via available CDDs, HDDs and average DDs for each location.

A past study (Stuart, 2011) used the DD model (as variable based degree-day model- VBDD model) for monitoring BEP and estimating BEU based on average outdoor air temperature. Stuart (2011), opined that observed energy used data are used to fit the VBDD model via estimation of the model parameters (M, x, and C), using ordinary least linear regression (OLS) in equation10.

Finally, the EPL is a model that indicates case buildings' thermal behaviour in relation to external temperature based on monthly data. The shortfall of the model is that it cannot account for non-linear building behaviour like occupancy, thermal capacity and gain fluctuations when based on daily data (CIBSE, 2006a; Ferreira, 2009).

#### 4.8 SAMPLING

The current research used a multiple-case study approach in establishing sustainable ways of improving EE of existing office building stocks in Nigeria compared to the UK. Hence, existing office building stock is the study population (Bryman, 2016). Therefore, ten office buildings were selected as a sample-case based on accessibility and convenience. These samples are five

office buildings in Nigeria and university's office buildings in the UK respectively. The strategy helped to benchmark samples (subsets) from the chosen population (Rachad, 2013).

#### 4.8.1 Sampling Frame

Here, study sample frame involves corporate staff of organisations in the case buildings, and members of the FM professional body in Nigeria. They are the potential participants that could be accessed from the population. This helped in mitigating against sampling's limitations such as unit non-response error due to the use of a web-based survey; and difficulties of contacting potential respondents (Bryman, 2008). Such anticipated risks were avoided by this strategic choice (organisations' staff and FM professional body).

A shortlisted sample of staff and professionals were chosen as the study representative sample amongst the sample frames. Probability sampling using simple random sampling technique; and non-probability sampling using both purposive and snowball sampling were used to gather quantitative and qualitative data (Knapp, 2014).

#### 4.8.2 Simple Random Sampling

The staffs of organisations in the sample frame were allotted sequential numbers where simple random numbers were chosen. The random numbers were based on 80% of the sample frame as the sampled population. The random mechanism chosen ensured that the sample is independent means that are free from subjective judgement and other biases. It ensured that the selection of one participant do not inadvertently affect the selection of other members of the sampled population (Henry, 1998).

Henry argues that the random selection process underlies the validity, credibility, and precision of collecting sample data and statistics. It also ensured that sampling errors like bias (over representation of the population) and variability (variability surrounding sample statistical results) are adequately reduced.

#### 4.8.3 Purposive Sampling

Study criteria were set out for the selection of participants for empirical data gathering exercises. The criteria for the occupants' survey are: participant must be a member of staff of the organisations working in the case buildings; they must have good experience of the case

building; have working experience within the building of at least twelve months; and must express voluntary participation in the research.

Criteria for the examination for owners and professional FM/ maintenance managers are, they must be: managers of facilities in respective organisations; members of the FM professional body, a senior management staff of case organisations; and their participation must be voluntary. Whilst, the criteria for the interviews with owners and facilities managers are, participants must be: MD/ CEO of an organisation within case buildings; staff of organisation managing case buildings; and owner of case building using it directly.

#### 4.8.4 Snowball Sampling

The identification of facilities / maintenance managers within the various organisations was done through a snowball sampling technique. The MD/CEOs and Owners of case buildings were instrumental in the selection of interviewees for information required for this study. They recommended the staff for interviews and directed them to freely express their expert's opinions on the research topic. They also helped in identification of and access to these individuals within organisations in case buildings who provided in-depth information about the energy efficiency concept being explored (Creswell, 2011).

#### 4.8.5 Sample Size

The study decision on the sample size for online surveys and interviews hinges on time, cost, and absolute size. Though the sampling is based on case study selection procedure, the issue of absolute sampling size within case buildings in the surveys was a concern. Hence, sampling is guided against error by increasing the size (about 80.0%) of samples within case buildings (Bryman, 2016).

### 4.9 RELIABILITY AND VALIDITY: QUANTITATIVE DATA

The quality of inferences drawn from mixed methods depends on the respective quality of qualitative and quantitative research results (Clark and Vicki, 2016). Thus, the current study used the individual traditional quality criteria for both mono-methods as the basis of assessing quality of data and results.

The concepts of validity and reliability is established in extant literatures (Fellows, 2008; Knight, 2009; Creswell, 2009b; Denscombe, 2014a; Clark and Vicki, 2016) etc. Validity is defined as “the degree to which inferences can be accurately made based on test score or other measures; and reliability is the accuracy of measurement procedures to produce the same score” (Clark and Vicki, 2016) (p166). Present study observed these quality standards because, the lack of reliability and validity could lead to erroneous conclusions and lack of credible study outcomes.

#### 4.9.1 Reliability

The study employed online questionnaire surveys in ensuring neutrality and reliability for data collected. Self-administered online questionnaire surveys were used for participants in case buildings, and for professional FMs. This ensured that respondents were given the freedom to answer questions without any interference and undue influences. The principle of half-split was used to check consistency of data set, and it was found that, answers from data for half of the questionnaire instrument were in the same pattern with the other half (Denscombe, 2014a).

Archival document analysis of the BEU data was used in case study buildings from the year 2011 to 2014. Energy bills and receipts for fuel and gas purchases for these buildings were used as an explanatory data collection. This ensured neutrality as data were entered as presented by each organisation, and there were no interferences with the collected data and procedure for generating each data set. There was consistency in the data generated for all case buildings. It also ensured accuracy of the measurement method in producing the same result if repeated (Clark and Vicki, 2016).

#### 4.9.2 Validity

The study’s validity was tackled based on internal and external validity approaches. Study ensured the following internal validity, quality control measures (Denscombe, 2014a; Clark and Vicki, 2016): dataset accuracy and error checks were thoroughly performed to ensure data reliability for the measure to be valid; all data entries were double checked in ensuring no mistakes; and data files were properly inspected before and after data entering exercises.

Dataset appropriateness was also cross-checked against the research questions and hypotheses for relevance, and they were found to be appropriate. Furthermore, the check for consistency

was carried out, and it was found that the profile of answers for this research data set was similar answers to similar research already undertaken (Denscombe, 2014a).

The case study BEU data collected through energy bills, gas and fuel purchases with receipts were cross checked with current meter reading. This procedure ensured adequate data reliability and similarity check was undertaken with all the buildings. The explanatory data set gives us the trend of energy consumption, including the pattern and type of fuel used in each building.

Study's validity was further strengthened via the use of: data source and methods triangulation; plausible rival explanation based on study prepositions; and logic model based on the framework (Yin, 2013). Whilst, study's control for external validity ensured that case buildings were samples of existing commercial building stock in Nigeria and the UK. Therefore, findings from study's statistical analysed data, and model validation via SEQM can be generalised. The research findings have the ability application of similar research, and phenomenon at a general level (Denscombe, 2014a).

#### 4.10 RELIABILITY AND VALIDITY: QUALITATIVE DATA

In achieving rigour for the study, one-to-one interview for participants within case buildings in Nigeria and UK was used as data source. Organisations' MD/ CEO, facilities directors, and other managers holding an FM portfolio (interviewees) were questioned. The formats of data collected were in talk and transcript captured via electronic Sony's T-Mark recorder (IC recorder, ICD-px333).

Some authors (Lincoln and Guba, 1985; Swanborn, 2010), introduced quality criteria for assessing standard for qualitative research design. Swanborn, opines that criteria such as trustworthiness, credibility, confirmability, transferability etc., are now being used in research studies. Therefore, the present work, applied these criteria in enhancing its validity and reliability.

#### 4.10.1 Credibility (Validity)

It has been argued that the credibility of qualitative research cannot be judged using the same criteria often used for quantitative study. Events and circumstances of its data collection can never be static, thus cannot be replicated (Lincoln and Guba, 1985; Denscombe, 2014a). It necessitated verification of qualitative data based on more pragmatic and subtle realistic perspective. Hence, the ideal of the use of credibility instead of validity, which involved steps needed for qualitative data to be reasonably accurate and appropriate (Denscombe, 2014).

The current study used respondents' validation as the first step taken to ensure credibility of the data. All transcribed data and findings were sent to respondents for correction and validation. The respondents could check factual accuracy and to confirm their opinion, views and experiences as expressed. It involved detailed transcribing of audio recordings of various interviews, and drawn conclusions based on these data, which added credibility to the research. Likewise, the likelihood of falsely reporting events was avoided, while academic reviewer reviewed all case reports to enhance accuracy of case study and strengthen the internal validity of the study (Yin, 2009).

#### 4.10.2 Dependability (Reliability)

The study also considered the methodological quality of extracting data based on "*whether the findings are accurate from the perspective of the researcher, the participant or the reader of the account*" (Creswell, 2013b; Clark and Vicki, 2016) (p166). Hence, vivid explanations of the method of qualitative inquiry, analysis (content analysis) and decision-making process were made and clarified through an audit trail and replication process for further inquiry. This gives the study good reliability, quality and makes its findings dependable as references for decision-making and scientific data citing.

#### 4.10.3 Transferability (Generalizability)

The procedure and methods for this study have been well documented in case of transferability on other circumstances. The principle of replication logic is too well entrenched in the current study to forestall the challenges of generalising findings from case study research. Though, the question of how to generalise based on findings from small population becomes difficult for the case study approach. This is equally a result of smaller sample size of case study when compared to the larger sample size in other methods. Hence, an imaginative process called

‘transferability’ has been applied. It is an alternative means of generalisation based on small numbers of qualitative data. It enables readers to use information about the case study to arrive at judgement on how it would apply in other circumstance, (Denscombe, 2014a).

#### 4.10.4 Confirmability (Objectivity)

During extracting data and findings of this study, care has been taken to ensure that findings are free from the influence of the researcher. The role of self in this study was considered. Hence, a positivistic approach was engaged in the path data were translated and applied. An open mind was also continued during the interviews and this approach was practiced for the data analysis. Data that did not fit into the analysis were not neglected and rival explanations were also checked and careful critic to see possible fitness problem (Ibid).

### 4.11 CASE STUDY LOCATIONS

#### 4.11.1 Nigeria

Nigeria is a Sub-Saharan Africa (SSA) country with climate variations from the coast to its northern part. Most tropical SSA countries are situated in the overheated zone of the world. The overheated world regions are categorised into: hot/warm and arid/semi-arid; warm and humid region; and temperate, both arid and humid region. Nigeria falls within the warm-humid region warm with latitude being 4° and 14° N (Ajibola, 2001). The climate of a location in Nigeria is determined by the time of the year, latitude of the location and the landscape (Batagorawa, Hamza and Dudek, 2011).

Past studies (Ajibola, 2001; Batagorawa, Hamza and Dudek, 2011), divide Nigeria into four climate zones namely: north- Kaduna; middle band- Abuja; south-Lagos; and extreme-south-Port-Harcourt. However, the country has two general climatic seasons: the dry season from November to March; and the rainy season from April to October. As explained by Ajibola (2001) is controlled by two factors, namely: *cooling and heating of the landmass of the Sahara Desert; and the heating and cooling of the large water body in the Atlantic Ocean*” (p58).

Available data (WBG, 2016a), shows that from 1900-2012, Nigeria’s average monthly temperature ranges from 24°C- 30°C annually. The lowest temperature recorded between Decembers and January, while the highest temperature is often recorded in April. Besides, her

average monthly rainfall ranges from 10mm- 220mm, and the lowest being in January to February while the heavy rainfall is often in July/September per annual.

#### 4.11.2 Lagos, Southwest Nigeria

Lagos state is an Africa mega city situated in the southwestern Nigeria, which lies within latitudes 6° 23'N and 6° 41' N; and longitude 2°42'E and 3°42'E. Also, it lies along the West African coastline sharing boundaries with: Ogun state (northern and eastern ends), Benin republic (western end), and the Atlantic Ocean/Gulf of Guinea (Southern end) (Iwugo, Arcy and Andoh, 2003). Lagos with a landmass of 3,345 square kilometres is a cosmopolitan city and the commercial nerve-centre of Nigeria.

Lagos has two rainy seasons with heavy rain that falls between April and July, and the light rain falls between October and November. There is a dry spell from August to September and the dry season from December to February. Harmattan wind from the Sahara Desert often comes with the dry season. The average temperature of Lagos is between January 27°C and July 25°C; and the highest temperature (29°C) is experienced in March (LSGMH, 2010).

Lagos was the former capital of Nigeria until the creation of Federal Capital Territory, Abuja as new capital in 1976; and whilst, the seat of government was finally relocated to Abuja on 12 December 1991. She has a population of about 17.6 million in 2006 with an annual growth rate of 3% (Ibid).

#### 4.11.3 United Kingdom

The United Kingdom (UK) is a European country with a total landmass of 243, 610sq. Meter, located in the temperate (temperate climate) region. She shared boundaries with Cyprus and Ireland; and her country's division comprises of England, Northern Ireland, Scotland and Wales, which segregate into: boroughs, cities, council areas, counties and districts (WorldAtlas, 2015).

UK is situated at the downstream end of the North Atlantic storm-track that is characterised with strong changes in precipitation (De Leeuw, Methven and Blackburn, 2015). Her climate seasonal variation is not severe and lies between the lack of heat (under-heating) and excessive heat (overheating) within a year (Szokolay, 2014). Climate data (WBG, 2016a), indicates from



1900-2012, UK's average monthly temperature was between 3.5°C and 14.3°C annually. UK lowest temperature is recorded between Decembers and February, while the highest temperature is frequently recorded from July to August.

Her average monthly rainfall likewise lies between 50mm and 130mm; and the lowest rainfall being in January to February, while the heavy rainfall is often in July to September per annual. The fluctuation in her precipitation on monthly, seasonal and inter annual timescales has a major impact on the society (De Leeuw, Methven and Blackburn, 2015). Her snow's solid precipitation occurs in a variety of minute ice crystals at temperatures well below 0 °C, but as larger snowflakes at temperatures near 0 °C (Metoffice, 2017).

The UK wind blows is from the south-west with extreme daily climate variability, and winds from other directions are quite frequent, and long spells of easterly or north-easterly winds are not unusual. Her mean daily sunshine figures reach a maximum in May or June, and are at their lowest in December. UK's sunniest town (St. Helier, Jersey) has an average of 1915 hours of sunshine per year. Whilst, her least sunny town (Ben Nevis, near Fort William), has an average of 736 hours of sunshine per year, that's just 16% of the total amount possible (Ibid).

#### 4.11.4 Chelmsford, Essex, Southeast UK

Chelmsford City is an Essex County town situated in the East Anglia Region of UK that lies within a semi-arid climate. She is located at 51.74 latitude and 0.47 longitude and elevation of 33meters above sea level (WorldAtlas, 2015). Chelmsford became a township in 1199 and UK's newest city in 2012; has a population of 168,000 as of 2011, with about 68,000 in surrounding districts (Broomfield. Chelmer village, Moulsham, Widford, Galleywood and Springfield) (Chelmsford, 2012). The city train station is about 30-40mins from the London Liverpool train station. Chelmsford is connected by train and road networks within 40miles radius with London, Colchester, Suffolk, Norfolk, Hertfordshire, Basildon and Harlow.

Chelmsford is part of East England, the driest part of England with an average rainfall of 450mm to 750mm (WorldAtlas, 2015). She has little rain comes in summer and moderate rain in the fall and wintertime. Available data (Metoffice, 2012; WorldAtlas, 2015), indicate Chelmsford has average annual record high temperature of 35.7°C with the hottest months being June (33.6°C), July (33.2°C) and August (35.7°C) between 1981 and 2010. Whilst, her record low temperature is recorded during the months of December to January (-20.6°C),

February (-13.3°C) and March (-11.1°C). Her average annual sunshine hours are 1,589.2 with July (209.9) and August (204.0) been the hottest, whilst, least sunshine hour is in December (47.4). Also, she has 591.8mm average annual precipitation with highest been recorded in October (64.1mm) and the lowest in February (39.2mm).

#### 4.11.5 Sustainable Development Indicator- SDI: Nigeria and United Kingdom

The World Bank Sustainable Development Indicator result (Table 2:1), for Nigeria and UK reveal large variation between the two countries. A population which is an indicator of energy access shows that Nigeria (177.5 million), is about three times larger than the UK (64.56 million), and has more citizens striving for limited energy resources. Thus, the pressure of energy demand on supply will be more in Nigeria than in the UK.

*Table 4:4: NG and UK SD Indicators.*

SN	WORLD BANK SD INDICATORS	YEAR	NIGERIA	UK
1	Population	2014	177.5 Million	64.56 Million
2	GDP (USD)	2014	\$568.5 Billion	\$2.989 Trillion
3	GDP Growth	2014	6.3%	2.9%
4	Inflation	2014	9.0%	0.1%
5	GDP per Capita (USD)	2014	\$3,203.3	\$49,297.0
6	GNI per Capita (USD)	2014	\$2,970.0	\$43,390.0
7	Energy Use (Kg of oil equivalent per capita)	2013	773Kg	2,978Kg
8	Electrical Power Consumption (KWh per capital)	2013	142KWh	5,407KWh
9	Access to Electricity (% of population)	2012	55.6%	100.0%
10	CO <sub>2</sub> Emissions (Kt.)	2011	88,026Kt	448,236Kt
11	CO <sub>2</sub> Emissions (Metric tonnes per capital)	2011	0.5tonne	7.1tonnes

Adapted from World Bank Group: (WBG, 2016b)

Likewise, the total GDP of both countries reflects their economic wealth based on financial resource available for each state. Based on GDP, UK (\$2.989 trillion), has more energy funding power than Nigeria (\$568.5billion), in providing energy infrastructure for production, supply and demand for the citizens. Furthermore, countries' GNI per capital shows that the people in the UK (\$43,390.0) have more purchasing power for electricity. Whilst, those in Nigeria (\$2,970.00), has far lesser amount available for purchasing electricity.

The deduction collaborates the energy use per capita for Nigeria (77kg) and UK (2,978kg); and their energy consumption per capita for both countries, Nigeria (142kWh) and UK (5,407kWh), people in Nigeria could experience energy poverty, whilst those in the UK able to access energy. This also confirms the country energy access as only about 56.0% of Nigerian have

access whilst all UK citizens (100%) have access to electricity. This might also be linked to the high CO<sub>2</sub> emissions (7.1tonnes) status of the UK.

#### 4.12 LIMITATION

The research encountered the problems of: lack of funding, time and disclosure; difficulties in getting approval from educational institutions in Nigeria due to bureaucracy, lack of disclosure and non-respond to online survey due to non-incentive in both countries. These imposed constraints of not having homogeneous multiple-case study that include education buildings for comparing similar. Nevertheless, the study model helped focus the research on limiting the variation in contrasting cases when compared Nigeria to the UK; in achieving study aim and questions.

#### 4.13 ETHICAL CONSIDERATION

The current study complied with Anglia Ruskin University Research Ethic Policy. Ethical approval was secured from the faculty research ethic sub-committee before commencement of study. It ensured participants' protection from risk of harmful effects, and secured their well-being (Clark and Vicki, 2016). The study commenced with the provision of survey and interview information pack to participants. The information pack clearly illustrated the purpose of study, procedure for study, issues of voluntary participation, vulnerability and safety, data usage, confidentiality and anonymity, and consent approval form.

They were asked to carefully read the information provided (in Appendix25), and upon their acceptance to participate based on the consent form, the procedure for the interviews and scheduled were also provided. The interviewees were sent the subject of interview discussions, which focused on contextual issues raised in the study model, the method of recording an interview and the interview period were stated in the information pack.

Yin (Yin, 2009; Yin, 2014), emphasised the important of care and sensitivity in conducting case study. He cited the details of care for ethical considerations (National Research Council, 2003) as including participants': informed consent, protection from harms and vulnerability, privacy and confidentiality, and equitable participations.

#### 4.13.1 Consent

The participants' voluntary consent was obtained before participation. They were offered the right to consent or decline to participate in the study (Thomas, 2016). Their participations were voluntary and no incentive was given as consideration for involvement. It was also made clear of their right to decline to answer any question and freedom to stop the investigation at any time. Moreover, assurance was given that in case anyone leave the study, any data and property collected from such individual will be deleted.

The consent form contains information on the researcher and the four basic consent questions. These questions were favourably answered by participants: I am happy to participate in this research; I am happy for the interview to be recorded via audio recorder; the anonymised records may be used to show other researcher and / or to students in classrooms; and I will like to opt out of anonymity and my identity used.

#### 4.13.2 Confidentiality and Anonymity:

Information from study's participation was treated confidentially and care was excised against compromising it (Thomas, 2016). Participants were informed of the option of opting out of anonymity where they don't mind having individual name and company revealed in this study. Additionally, if they choose to remain anonymous in the study, names were coded and original identifications were stored safely for the duration of the research. Also, audio recording was stored safely and destroy after research completion. Finally, the accumulated information is utilized only for the PhD study and contributions to likely academic publications.

#### 4.13.3 Vulnerability and Safety

The current study will not cause any physical, emotional or any other risks to participants or non-participants alike. Each case building's facility manager gave the researcher access to energy bills, meter reading/ data acquisition system, and building architectural/ service engineering drawings. Also, individual participation was subject to the person being 18years and above for protection against vulnerability (Thomas, 2016).

The researcher did not encounter any risk except, risks due to human error such wrong interpretation or measurement of building drawings, wrong calculation of energy use data from

energy bills or data acquisition system. Still, there was no risk to life or infringement on the privacy of individuals and properties due to the established approval procedure.

Finally, the risk of breach of data protection law was handled by storing all paper documents and electronic data in securing locks, university computer and my personal laptop with secured password. It is only the supervisory team member and the researcher that has access to these documents.

#### 4.14 STRUCTURAL EQUATION MODELLING- SEQM

The use of SEQM dates to early 20<sup>th</sup> century, when the foundation for factor analysis and the measurement model (in SEQM), was introduced by Spearman. This was further developed later by Wright through his path analysis model (Wright, 1918, 1921; cited Blunch, 2008). This was a precursor to the introduction of covariance-based SEQM (LISREL- linear structural relations programme) by Joreskog in 1973, a research technique currently being used by several researchers (Haenlein and Kaplan, 2004).

SEQM is an operative and an optimum technique for studying and testing relations between mediator variables. It is an estimation model that enables the handling of multiple exogenous and endogenous variables as well as unobserved (latent) variables that are specified as a linear combination of observed variables (Jenatabadi and Ismail, 2014). Its use involved the clear delineation of concepts developed in the current model. The study's ideas are conceptualised and operationalized via provision of adequate measurement instruments for a valid concept. Likewise, the identification of the observed independent and dependent variables is important in defining the various concepts in an SEQM (Blunch, 2008).

Blunch (2008), further explained that SEQM consist of two parts, namely: the structural model that describe the causal relations amongst latent variables, including mapping of their networks; and the measurement model that define the connections between the latent variables and their manifest indicators. A latent variable cannot be measured directly, they are measured through indicator (manifest) variables. The interactions between the manifest variables (measurable indicators) enable researchers, to uncover the causal structure amongst the latent (non-measurable) variables. SEQM is a graphical representation of a set of integrated multivariate

technique such as: measurement theory, factor analysis, path analysis and regression analysis, including simultaneous equation modelling (Hou et al., 2014).

It has been widely applied in previous studies: for the tourism industry (Ko and Stewart, 2002); in validation of theory (Yoon, Gursoy and Chen, 2001); and in the field of software evolution, theory and education (Steiger, 2001); and in the study of software development, theory and education (Steiger, 2001). SEQM has also been used to study environmental sustainability and BEP (Hu, 2013); environmental proactivity and financial performance of manufacturing sectors (Sen, Roy and Pal, 2015); and the influence of corruption on several countries' (133nrs) population health outcome (Poortinga et al., 2012).

The use of SEQM in extant literature for reducing BEU and decarbonisation of the built environment field is quite unknown until recently. The first known work, is its application for the explanation of residential energy use in England (Kelly, 2011). Kelly also used it for modelling behaviour, technologies, and policies for decarbonising UK's heterogeneous building stock (Kelly, 2013). Also, it was used in understudying the individual motivational factors in the acceptance of demand-side and supply-side strategies to reduce carbon emissions, via Value-Belief-Norm model (Ko, Hwang and Kim, 2013). Recently, it was used in a study for investigating the similarity and variances in consumers' choice for smart grid meters in residential buildings in Taiwan, Korean, Indonesia and Vietnam (Chou et al., 2015).

Amongst these studies, the current studies share some similarity with the work of Kelly (2013). Kelly used SEQM to examine the 'complex socioeconomic, socio-dynamic and technical, physical systems' that fortified energy use in the UK's residential and heterogeneous building stock. The work considered in detailed such factors as: EE, behavioural, technology, policies etc.; and quantified their direct, indirect and total effects on residential energy demand. The study produced an energy-demand model that used a combination of socio-demographic, behavioural, physical and environmental factors to predict the daily variation of mean internal temperature demand.

In the current study, SEQM is used to examine the factors that contribute to improving EE performance of heterogeneous office building stocks in Nigeria and the UK. It attempted to quantify the causal relationships between driver's factors (solutions) in relation to BEP model

to explain energy use; and the role of combined use of SSP and SFM for building energy management in corporate organisations.

#### 4.14.1 Justification for SEQM Analysis

The study used SEQM-based multivariate regression analysis to investigate the relationship between several factors that determine BEP improvement (Hinton, 2004). The analysis helped in the investigation of several factors, which constitute SMB for improving BEP. The correlation between these factors might indicate causal relations, and might arise due to other exogenous (third) factors. The analyses helped identified the causal relationships and co-axial associations (correlations) amongst factors that propel BEP improvement. Hence, it is preferred to other tradition methods of analysis.

Other tradition method of multiple regression analysis and analysis of variance (ANOVA) are associated with certain limitations. They are based on the following assumptions that: all experiment involves a simple model structure (in the case of regression-based approach); all variables are considered observable; and all variables are measured without errors (Haenlein and Kaplan, 2004). SEQM has the merit of overcoming these limitations. It can handle multiple exogenous and endogenous including observed and latent variables, therefore, it adoption for current study.

The study involves several factors that have been confirmed to be impacting BEP, therefore they are multi-variates. Some of these factors are mediating or moderating, dependent and others independent variables. Haenlein and Kaplan, argued that the potential effect of mediating variables may result in some dependent impacting other dependent variables. Also some variables are observed indirectly and therefore outside the assumption of being observed directly. Additionally, traditional methods do not consider measurement errors (random errors caused by the order of items in the questionnaire or respondent fatigue; and systematic error caused by measurement method).

SEQM has the advantage of flexibility of concepts' linkage as the current study hypothetical model involves multi-path linkage. Hou et al., (2014), reaffirms this by expounding that a latent variable can be a dependent variable in one set of relationship, and at the same time independent variable in another set of relationship. SEQM is part of the research process that helps

determine the structural relationship between current study variables (Kelly, 2011), depicted in the study's methodology framework.

#### 4.15 MULTIPLE-CASE STUDY PROTOCOL

The study protocol used the research framework as replication logic on case buildings. The selection of cases and data collections are based on factors and contextual variables defined within the framework. Herein, the theoretical framework developed based on prior knowledge shaped current study's protocol. Case selection and definition of measurements are considered in each case as a whole-case (Yin, 2014).

Thus, each case building is considered as a whole-case, where facts and determinations are based on convergent evidence for the case. The same study's procedure is repeated for the ten cases, but with modifications (*Figure 4.1*), as follows:

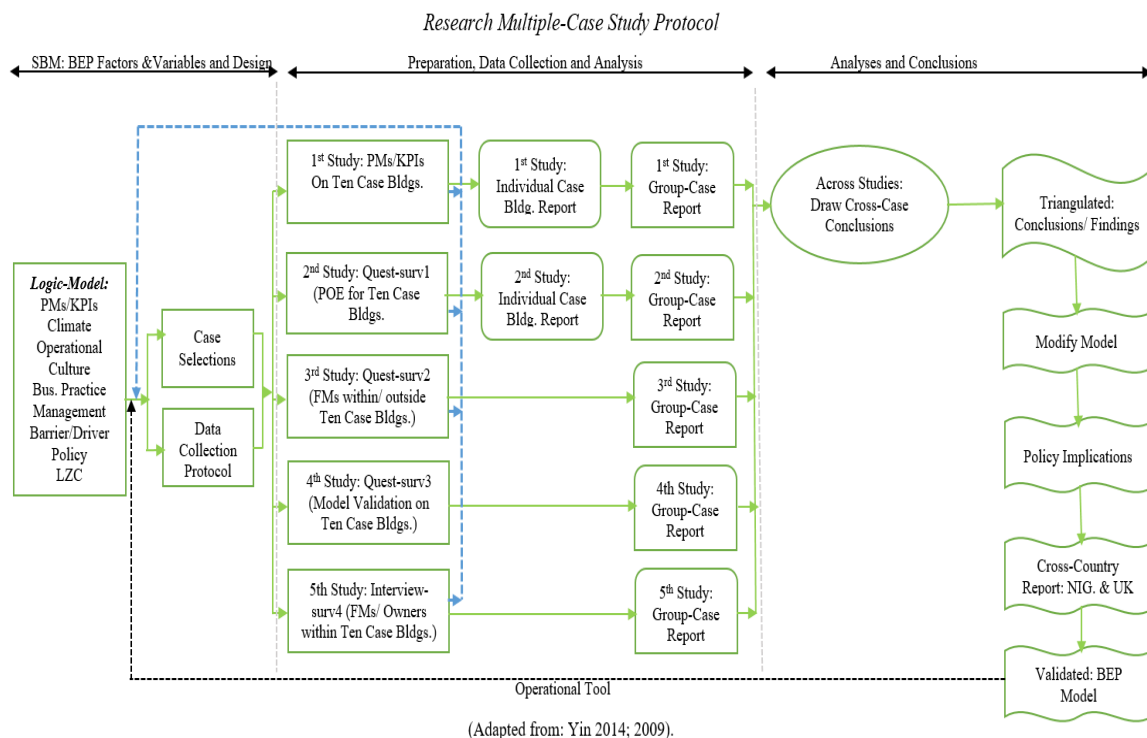


Figure 4.1: Research's Multiple-Case Study Protocol

The 1<sup>st</sup> and 2<sup>nd</sup> studies used case's reports for individual case as whole report, and later converged into groups' report (Nigeria and UK). The 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> studies' reports are based on a group basis. The study's model is used as replication-logic in collecting and analysing



data for each building. Nevertheless, data collection, analysis and reporting method for the five studies is established along the same replication-logic.

Study analysis is further converged through triangulation, and cross-case conclusions drawn based on grouping (NIG and UK). The triangulated conclusions and determinations were used in modification of the study's model. The policy implication of the findings was suggested based cross-country report.

Finally, the two dashed-line feedback loops were provided as procedures for cross-checking new findings against study's logic-model (Yin, 2014). The blue dashed-line represents where new findings are found during case study data collection and analysis. Here, the findings are checked against initial theoretical prepositions before proceeding. Whilst, the black dashed-line represents a cross-holding back the modified model against initial preposition as a validation procedure.

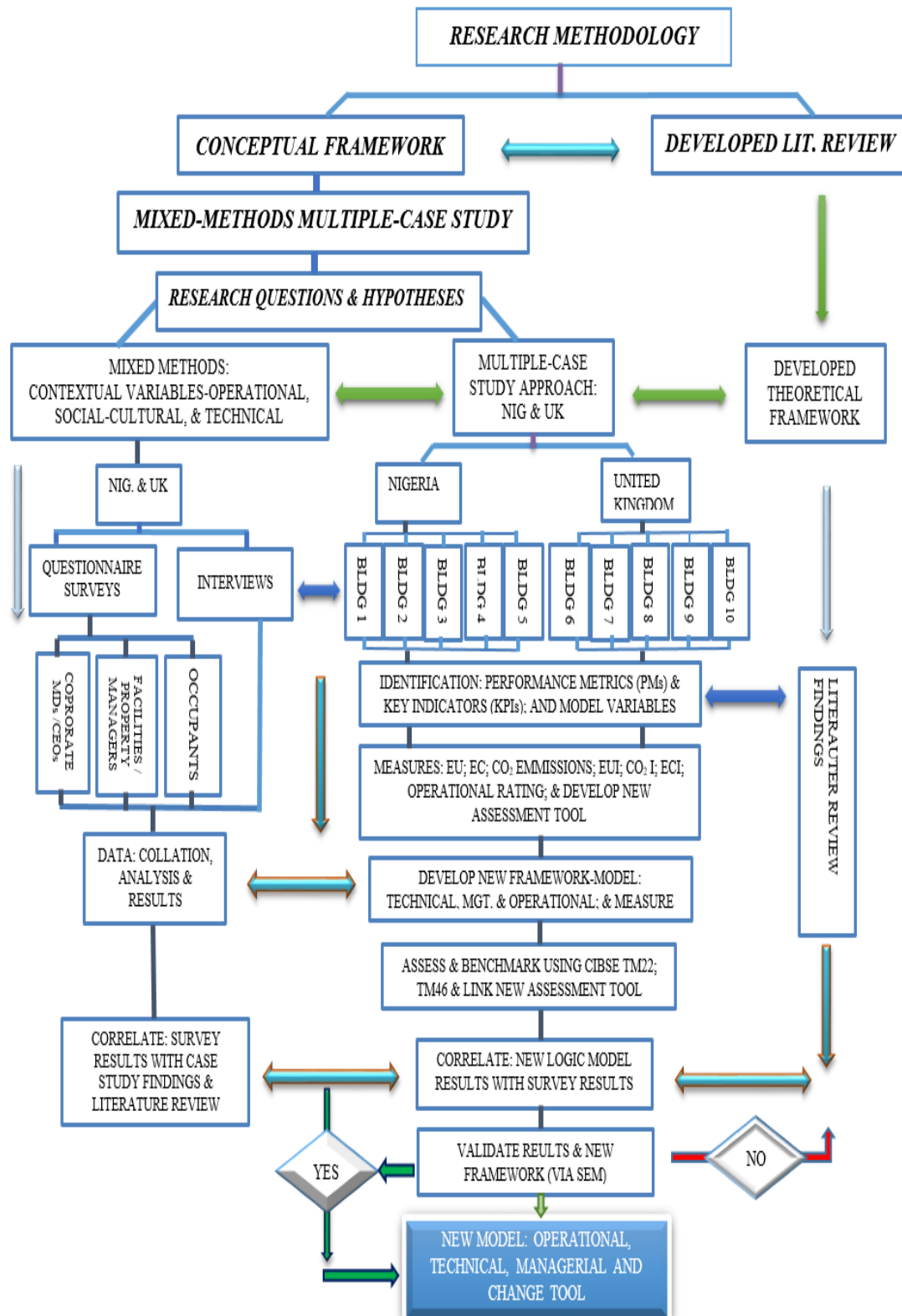
#### 4.16 RESEARCH METHODOLOGY FRAMEWORK

The study's methodology (Figure 4.2), indicates the functional stepwise procedure undertaken to accomplish the study's aim and objectives. The inquiry started with a review of extant literatures and development of conceptual framework based on prior knowledge concurrently. The study's theoretical framework development continued till the completion of the inquiry.

Thereafter, it engaged three distinct approaches, namely: mixed-methods, multi-case study; and theoretical framework validation to further the enquiry. The mixed-methods involves a quantitative approach that used three separate online questionnaire studies (occupants, owners/CEO and professional FMs). The qualitative approach involves interviews for MDs/CEO and FMs).

The second approach involves multi-case study of BEP based on technical energy assessment. It used the OS and BEU data for 4 years (2011-2014) in assessing and benchmarking BEP within and across studies. Finally, the SEQM validation approach (third), came after the overall approach known as mixed-method multiple-case study.

## METHODOLOGY FRAMEWORK



Methodological Framework (Mafimisebi, et al., 2016)

Figure 4.2: Study Methodological Framework

#### 4.17 SUMMARY

The chapter expounds on the research philosophy, design and methodology used for the study. It illuminated the choice of adopted mixed method for data collection and analysis within the multiple case study approach. Its rationale, based on the advantage of allowing for replication logic in obtaining stronger validity and reliability is specified. It further explicated on study's criteria for selecting the case buildings based on access to data, satisfying rigour and robust investigation.

Procedure for the mixed-method multiple-case study approach is illustrated via the study's methodological framework. The study's five studies, namely: occupants', professional FMs, and validation questionnaire surveys; interviews for owners/ MD and FMs; and case buildings' energy consumptions assessment and benchmark study are well specified.

The study's procedure for reliability and validity was exposed. Whilst the data source and methods triangulation; plausible rival explanation based on study prepositions; and logic model based on the framework used in strengthening validity were explained. Eventually, it expounds on the rationale for the usage of SEQM for validation as precursor to the study's research methods that explained the techniques for data collections and analysis.

## 5 Chapter Five: Research Methods and Analytical Framework

### 5.1 INTRODUCTION

The section described the procedures, tools and techniques used to gather the required data for BEP theoretical model. It presented the research tool used in data collection as physical survey, online study, audience interview and archival document analysis. The chapter explained the differences between research design and methods, and drew attention to the need for intensive forms of research method for current study. Finally, the chapter exposed on all the studies used in the research, the protocols undertaken and the analytical techniques used.

### 5.2 RESEARCH METHODS

Some authors (Clark and Vicki, 2016; Bryman, 2016), have differentiated between research design and methods. Research methods are about the devices used for collecting data for research analysis. It involves a set of procedures, tool and techniques that provide a base for knowledge (Organ, 2015). The research design is a framework for data collection and analysis (Bryman, 2016). It is also, a formal plan for achieving the research aim, which defined set of procedures for collecting, analysing and interpreting data (Clark and Vicki, 2016).

Two forms of research methods namely: intensive and extensive approaches have been identified in past studies (Easton, 2010; Organ, 2015). The intensive method involves statistical analytical research that focuses on patterns and regularities. It also incorporates context with causal explanation but its statistical generalisability is limited. The extensive method uses only interview and qualitative analysis (Organ, 2015). The current study used the intensive approach.

The study's mixed-methods multiple-case studies embraced the intensive research method underpinned by sequential explanatory mixed-methods, design-logic and concurrent triangulations (Creswell, 2015; Clark and Vicki, 2016). Also, it used a pragmatic approach, which allowed for triangulation in between-methods for collections, collations and analyses, including freedom of interpretation of data (Denscombe, 2014a).

A similar approach was used in past studies (Lewis, 2012; Junghans, 2013), as a procedure for determining appropriate frameworks for: improving EE of building stocks; energy and maintenance management decision-making; and portfolio analysis of EEP of buildings etc. These studies also engage the use of physical surveys, document analysis, questionnaires and interviews as tools for data collection and analyses on multiple-case studies.

The used of more than one method in the current study, gives better results by seeing it from more than one angle (Denscombe, 2014a). The choice of between-methods (methodological triangulation) for contrasting findings from alternative methods within the case studies; and the use of theory triangulation (using more than one theory), in relation to data collection and interpretation are adopted for this study. This allowed for achieving more worthwhile findings of the inquiry.

### 5.3 RESEARCH TOOLS

The present study used these tools: web-based survey, technical survey, interview and archival document analysis for data collection.

#### 5.3.1 Online Survey

Three self-complete web-based surveys were used for this study. The web-based surveys were designed to enable respondents work independently, providing their own answers at their own pace and time (Denscombe, 2014b). The respondents' capability was also taken into consideration, as organisations' staff in study case buildings was target sample population. It ensured that participants were well informed and educated to at least high school level.

The flexibility of contacting respondents was considered, therefore, only resident staff of organisations within case study buildings were sampled for practicality and resource constraint. The reliability of respondents' rate of response was considered; and there was consistent follow-up on all respondents by a devoted staff in the chosen organisations and the researcher. The questionnaire design based on structured questions with simple ticking options for answers also, served as motivation for the good responds. The questions were accurate, clear, precise, honest and complete with relevant sections (Denscombe, 2014b).

### 5.3.2 Archival Documents Analysis

Documents /portfolio analysis is used as a tool in the present study. The content analysis of relevant researches, regulations, report documents such as: UKs' CIBSE TM22 and TM46 (2006; 2008): CIBSE TM22- Energy Assessment, Reporting & Methodology, TM39-Building Energy Metering, TM41- Degree-day theory & applications; and TM46-Energy Benchmark. The theory orientations, methodology, analysis and findings of these documents were found useful application in the current study. Furthermore, archival documents such as: energy bills, architectural and engineering drawings, and account booking-keeping records formed part of multiple sources of evidence as portfolio analysis for the study.

### 5.3.3 Interview

Interview is either in structure, unstructured, or semi-structural form in researches, however, the present study used the semi-structured interview. This course permits the choice of choosing topics from literature before beginning participation. It also helps maintain consistency in the data collection, ensuring that same concepts cover for each interview (Corbin and Strauss, 2015).

The semi-structured interview help develop study ideas through flexibility on issues bothering on contextual variables of the research. This is necessary especially as it bother on SP, FM and other drivers for BEP in sub-Saharan Africa countries. Also, it helps the researcher in having series of selected questions as interview guide, however, with potential of varying their sequence during each interview (Bryman, 2016).

Sustainability, FM and BEU as concepts have been understudied in the region. The use of interview for this purpose is useful in gathering data that deals with a sub theme in the depths and in details. This helps to give valuable insights based on the depth of information gathered on each sub theme. It was made possible by giving all respondents the priority to express their opinion, ideas, and identification of what each of them regards as crucial factors (Denscombe, 2014b).

Despite, the strength of semi-structured interview used for the study, it has however been criticised for making it difficult for covering topics or problems relevant to participants that are not asked. Also, some participants might have certain issues in mind that are not asked by the

interviewee. While the potential of building upon concepts derived from previous interviews is higher with semi-structured interview (Corbin and Strauss, 2015).

The study ensured that participants are given the chance of adding opinions that are outside interview questions. Moreover, respondents were told that they are free to present the relevance theme if not ask during the consultation. Likewise, the study ensures minimization of follow-up concepts build-up during each consultation.

## 5.4 DATA COLLECTION TECHNIQUES

The current study's data collection was done in three phases. Also, as part of the case study protocol, it mapped the procedure of data collection and their respective purposes (*Table 5:1*). This involved pilot test, physical survey; archive document analysis; three online questionnaire surveys; and interview as a strategy for collecting main data in two stages.

Table 5:1: Data Collection Techniques

Study Phase	Data Collection Tools	Purpose	Buildings Used	FM
1st Phase	Online Pilot Questionnaire Survey	Pilot study for selection of case buildings and questions refinement	Random buildings (NG. & UK)	Nil
2nd Phase				
1	Physical /Technical Survey	Assessment: HVAC types, and case buildings based on logic model variables for ranking	Ten study Case buildings	Nil
2	Archival Document Analysis	Empirical BEU Data; and BEEP based on Model Factors		
3	1 <sup>st</sup> online Questionnaire Survey	Contextual Variables for BEEP		
4	2 <sup>nd</sup> online Questionnaire Survey	BEE PMs/ KPIs; Sustainable Policy & FM	Nil	FMs
3rd Phase				
5	3 <sup>rd</sup> online Questionnaire Survey	Model Validation for Contextual Variables via SEM	Ten study Case buildings	Nil
6	One-on-One Interviews	BEE factors and contextual issues		

Data Collection Technique: Study's Author, 2016.

### 5.4.1 Phase One: Pilot Study

The study used an online pilot survey through survey-monkey. It was performed randomly on accessible buildings based on approval from potential case study's participants. The pilot study aimed to refine the questionnaires' content and data collection procedure in the study (Yin, 2014). It was a self-administered questionnaire for, which organisations in seven case buildings in Nigeria and one in the UK participated between November 2014 and April 2015. Selection of pilot cases is based on accessibility, convenience and geographical locations.

The scope of inquiry covers substantive issues of improving the conceptualisation of study theoretical model. The pilot survey has the same format with quest-surv1 (Appendix22: Quest-Surv1), except only two case buildings were listed on it. Also, 150 surveys were sent out and 120 questionnaires were completed and returned, which represented 80% response rate. Moreover, its methodological purpose is to give insight into field questions and potential circumstances in the research; and enable the approval of case buildings for the study (Yin, 2014). Still, the inability to obtain approval for all case buildings and access to their BEU data for final study, were conditions that affected the non-utilization of the pilot test result.

#### 5.4.2 Phase Two: Main Data Collection 1

The second phase of the study involved actual data collection for the research. A physical walk-through survey was performed for each case study building in both countries. Also, archival documents were collected for analysis. The two online surveys: quest-surv1 (case buildings' POE) and quest-surv2 (FM professionals in Nigeria) in Appendix23: Quest-Surv2 were used.

The Likert's 5-point and 7-point ordinal scales were used for comparing response data of different categories for the online questionnaire surveys. Measurement of the difference in data collected between periods was used based on an interval scale for direct comparison and contrast. The ratio data were used based on absolute reference point or base year.

##### *I. Physical Building Survey (Walk-through)*

The current study used physical walk-through as technical survey. It aimed at the physical assessment of the requirement for BEE from organisations, and EE installations in the ten case buildings based on the BEP framework. The study's selection criteria guideline for the case buildings was applied. The building survey was conducted using the study developed technical survey tool known as 'operational sustainability tool' (OST). The OST was applied as the same method for all case buildings to guide and ensure that comparative dataset is gathered.

The OST tool helped assess the case buildings based on organisations' EE capability, the impact of government policy and BEE installations in the case buildings. The weighting scale (Appendix6: OS Toolkit Weighting Scale Summary), grouped BEP framework variables into: organisation policy, government policy, organisation practice, installation and behavioural for



which a scale of -2 to +2 was assigned. Likewise, technical survey helps to initially categorise the operational sustainability (OS) of case buildings based on the BEP framework contents. The OST assessment aided in the initial classification of the case buildings into poor, average, serious, very good and excellent OS.

The walk-through surveys were taken in charge by the researcher and assisted by an FM staff from each organization. The UK case buildings' survey took place between 8<sup>th</sup> and 12<sup>th</sup> December 2015. Whilst, the Nigeria case buildings' survey took place between 14<sup>th</sup> and 17<sup>th</sup> April 2015. However, the OST is a perspective tool that is based on the technical skill and experience of the assessor; hence it can affect the surveyor's rating of each case building.

The OST rating (Appendix7: OST Weighting Scale Application), was applied based on the perceived association of the contents with the organisation and the building. For instance, mitigation and adaptation policies are grouped under organisation policy for CCH, therefore the rating is: a case building in which such written policy is absence, not practiced and the MD and FMs are unaware (is rated -2); when it is absence but they are aware (-1); when the organisation is planning such policy and they practice it (0); when the organisation practices such policy, but unwritten (1); and when the organisation evidenced written practice (it is rated 2). Others are rated using similar technique.

Thereafter, a weighted percentage (equation14) is applied to get individual percentage score. The OST has 56 variables and a maximum score of 2, while, the maximum overall score can only be 108 (100%) for any building. Therefore, the OS rating will be:

$$OS.rating = \frac{actual.score}{N\ variable \times max\ .score} \times \frac{100}{1} \dots\dots\dots Equation14$$

The scores are then rated based on OS category as thus: 'E' = ≤ 19.0%; 'D' = 20.0- 39.0%; 'C' = 40.0- 59.0%; 'B' = 60.0- 69; and 'A' = ≥ 70.0%.

## II. Empirical Building Energy Used Data

The 2<sup>nd</sup> phase of data collection also involves, a collection of time series energy used (BEU) data for the ten case study buildings. A four-year monthly data was collected based on available historical records for accounting period of 2011 to 2014, with 2011 year as the base year. Data

were sourced through document analysis. The data is used for the measurement of the independent factors (BEU, CO<sub>2</sub> emission, BEC, BEUI, BCO<sub>2</sub>I, and BECI) that impacts BEP of case buildings as depicted in the logic model.

Archival documents such as: book keeping, records for energy bills from accounts department; architectural drawings, and receipts for the purchases of fuel were used. In addition, physical photo shoots and spot measurement of building size were carried out. It was done to ascertain the approximate net enclosed floor area for buildings for which architectural drawings are not readily available.

The data are organised into monthly bills: metered grid electricity and gas, electricity estimated payments, and diesel/PMS fuel purchases (*Table 5:2*). The individual case building's monthly BEU and BCO<sub>2</sub> emissions were estimated from the monthly invoices and account's bookkeeping.

Table 5:2: Primary Indicators (PMs/ KPIs) for Case Buildings

Primary Indicators (Indices)	CASE BUILDINGS (NIGERIA: B101-105; AND UK: B201-B210)									
	B101	B102	B103	B104	B105	B206	B207	B208	B209	B210
PMs/KPIs										
Monthly Metered Grid Electricity Bill	√	√	√	√	√	√	√	√	√	√
Monthly Metered Gas Electricity Bill	-	-	-	-	-	√	√	√	√	√
Monthly Estimated Bill	√	√	√	√	√	-	-	-	-	-
Monthly Fuel Purchase	√	√	√	√	√	-	-	-	-	-
Monthly EU	√	√	√	√	√	√	√	√	√	√
Monthly CO <sub>2</sub> emission	√	√	√	√	√	√	√	√	√	√

The dataset for Nigeria comprises of: The Power Holding Company of Nigeria Ltd (PHCN) monthly energy metered-bills; estimated-bill for each case buildings; company's receipts for the purchase of premium motor spirit (PMS) and Diesel (AGO) used in powering generators used in the buildings in Nigeria.

The data for case buildings in Chelmsford, UK are provided by the Facilities & the Estate Department of Anglia Ruskin University Chelmsford. The UK's buildings are fitted with data acquisition and automation systems, where an hourly time series record of BEU data was captured. The utility bills for these buildings were also provided. The utility bills were verified, analysed and cross checked against the records for reliability and validity.

### III. 1<sup>st</sup> Online Questionnaire Survey (Quest-surv1): Explanatory Dataset

The 2<sup>nd</sup> phase also involved the online Quest-surv1 (in Appendix22), developed for collecting responses from case buildings' users: owners/ MD of organisations; occupants (students/ staff); and in-house maintenance/ Facilities managers in Nigeria and UK. The Quest-surv1 is a post-occupancy evaluation (POE) for in-depth assessment of the ten case buildings' comfort and BEP.

Quest-surv1 has twenty-four questions that categorised respondents' information into different sections (*Table 5.3*): demographics, knowledge and use of case study buildings, knowledge of installed technologies and perceived benefits, measurement of building's comfort, occupant energy consumption behaviour, and awareness of global environment issues. It was administered in both countries between April and October 2015. Too, 200 questionnaires were sent to participants via survey-monkey platform, and 166 questionnaires were completed and returned, which represented 83% response rate.

Table 5.3: Quest-surv1 on POE for Case Buildings

Quest-surv1: POE (Explanatory Data)	Questions	Study Case buildings									
		B1 01	B1 02	B1 03	B1 04	B1 05	B2 06	B2 07	B2 08	B2 09	B2 01
Demographics	Q1-4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Knowledge of Building & Use	Q5-7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Operational- Technology	Q8-9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate- User comfort & BEEP	Q10-11	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Managerial-Model variables & BEU	Q12	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cultural-Energy Behaviour	Q13-15	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Operational- Solutions	Q16	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Technical- Solutions	Q17-18	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cultural- Awareness on Environmental Issues.	Q19-20	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Driver- preposition	Q21	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cultural- User's Awareness Preposition	Q22	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Barriers context	Q23	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Drivers Context	Q24	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

The enquiries contained in quest-surv1, was an improved version of the pilot survey and it listed the ten approved case buildings. It aimed to seek the opinion of participants on factors that affects each case BEP. It obtained the perception of case buildings' user on building comfort and BEP including climate change.

### IV. 2<sup>nd</sup> Online Questionnaire Survey (Quest-surv2): Explanatory Dataset

Lastly, the 2<sup>nd</sup> phase of the study involved, administration of the 2<sup>nd</sup> questionnaire survey (in Appendix23). Quest-surv2 was used to gather data on metrics and indicators for assessment, and the importance of SP and FM on BEP. It was administered only to FMs, and staff of facilities management/ maintenance departments; and it ran from December 2014 to September 2015. The aim is to have expert opinion on these technical subjects.

The survey contained twenty-five questions that categorised into nine sub-sections (*Table 5:4*): demographics; impact of FM roles and SP; identification of companies with embedded SP and EE policy; barriers and drivers to EE and FM; building technology embedment and awareness; factors influencing BEU; identification of managerial and technical solutions; and identification and effectiveness of metrics and indicators.

Table 5:4: Quest-surv2: Professional Perception on PMs/ KPIs and SP/ FM

Quest-surv2: PMs/KPIs & SP/FM (Explanatory Data)	Questions	Professional FMs / NIG. Case buildings	Professional FMs/ UK Case Buildings
		Case-Group1	Case-Group2
Demographics	Q1-7	√	√
Barriers & Drivers: FM/ SP	Q8	√	√
Operational- Firms with SP & EE policy	Q9-10	√	√
Barriers & Drivers: EE & FM	Q11-12	√	√
Technical Solutions- Technology & Awareness	Q15-17	√	√
Factors influencing BEU/ BEE	Q18	√	√
Managerial Solutions- FM's priority	Q19	√	√
Managerial & Technical Solutions	Q20-22	√	√
Operational- Identification of PMs & KPIs	Q23-25	√	√

Quest-surv2 dealt with the opinions of professional FM within and outside case buildings. The explanatory data obtained is derived from twenty-five questions, which are organised into two study groups (NIG and UK). The outcome of the pilot study informed this separate study for professional FMs. Most respondents do not understand the technical terms associated with BAM, energy retrofits, and FM roles based on non-response associated with these inquiries. Hence, the need for quest-surv2 for, which 100 questionnaires were sent out and 47% response rate was recorded.

#### 5.4.3 Phase Three: Main Data Collection 2

The 3<sup>rd</sup> phase of the study involved administration of one online questionnaire and one-on-one interviews as tools for collection data.

#### V. 3<sup>rd</sup> Online Questionnaire Survey (Quest-surv3): Explanatory Dataset

The 3<sup>rd</sup> questionnaire survey (Appendix24: Quest-Surv3), was used for the validation of variables identified from the study framework. The purpose was to measure and validate all the indicators of critical factors identified in previous studies; and validate the study's framework contexts as indicators of a BEP model. The study participants are: students and staffs in case buildings; building owners and CEOs of organisations; and professionals (FMs, in-house maintenance/ FMs, and other allied professionals in the construction industry), in both countries. Quest-survey3 was carried out between August and November 2015. Also 180 questionnaires were sent out for, which 120 were returned with 66.7% rate of response.

The dataset from quest-surv3 was obtained with twenty questions (*Table 5:5*). The questions are organised into fifteen sections for the two study groups: demographics, operations, management, barrier/ drivers, LZC option and cultural context including hypothesis and ranking of model variables.

Table 5:5: Quest-surv3: Structure of Explanatory Dataset

Quest-surv3: Model Validation (Explanatory Data)	Questions	Nigeria Case buildings	UK Case Buildings
		Case-Group1	Case-Group2
Demographics	Q1-4	√	√
Operational Context - Technical solutions for BEE	Q5	√	√
Managerial Context- Managerial solutions for BEE	Q6	√	√
Barriers & Drivers Context- embedded SP/SFM for BEE	Q7	√	√
Cultural Context- identification of BCT variables	Q8	√	√
LZC Option- Identification of Renewable solutions	Q9	√	√
Operational Context- Assessment /Benchmark Hypothesis	Q10	√	√
Research Hypothesis	Q11	√	√
Barriers & Drivers Context- BEE	Q12	√	√
Operation Context- Tech. Maintenance/Retrofit for BEE	Q13	√	√
Policy Context- Reg. Policy & Inst. Framework for BEE	Q14	√	√
Operational context- Tech. FM as drivers for BEE	Q15	√	√
Barriers & Drivers Context- Model variables driving BEE	Q16	√	√
Operational Context-Tech. identification of PMs/ KPIs	Q17-19	√	√
Model Variables Ranking as factors impacting BEU/BEE	Q20	√	√

Initially, traditional descriptive and non-parametric statistical analysis via multiple regression was planned for quest-surv3. Therefore, sample size of 120 was considered adequate. However, the researcher opted for the use of SEQM during the study. SEQM was used to validate correlation between manifest and their latent variables; and latent variables and BEP model in study model. The sample size might cause problem for future study, as a sample size of 120 is considered low for SEQM with fifty-six variables.

## VI. Face-Face Interview (Interv-surv4): Exploratory Dataset

The third phase of data collection for this study involved in-depth face-to-face interview with FMs, owners, and MDs /CEOs of companies using case buildings. Semi-structured questions were used for one-on-one engagement with interviewees in Nigeria and UK (Appendix26: Details of Participants' Interview- Interv-Surv4). The interview survey served as confirmatory and complementary data collection instruments for fulfilling the required robust and rigorous for study.

The one-to-one interview tools used help obtained opinions and deeper understanding of stakeholders on sub-themes drawn from research hypotheses and questions. Themes used for the interviews were based on the eight contextual lenses. The issues based on the study developed model are: barriers and driver's context, operational context, cultural context and management context. Others include climate context, business practice context and low-zero carbon optional context.

Data is collected through thirty-one questions used in securing the opinions of MDs (4nrs) and FMs (1nr) in Nigeria's; and FMs (2nrs), in the UK's case buildings. The data are also structured into the two identified study groups (Table 5:6).

Table 5:6: Interv-Surv4: Structure of Exploratory Dataset

Interview-Surv4: Exploratory	Questions	Nigeria Case buildings					UK Case Buildings	
		Case-Group1					Case-Group2	
Interviewees		Int-Case1	Int-Case2	Int-Case3	Int-Case4	Int-Case5	Int-Case6	Int-Case7
Comfort of Building	Q1	✓	✓	✓	✓	✓	✓	✓
Technology: Building	Q2-3	✓	✓	✓	✓	✓	✓	✓
MPs/KPIs: Choice	Q4-5	✓	✓	✓	✓	✓	✓	✓
Operational: SEM, energy billing	Q7-9	✓	✓	✓	✓	✓	✓	✓
Barrier/ Driver: FM and SP	Q10-16	✓	✓	✓	✓	✓	✓	✓
Bus. Practices: Supply Chain & Corruption	Q17-19	✓	✓	✓	✓	✓	✓	✓
Climate: Climate change & BEU	Q20-21	✓	✓	✓	✓	✓	✓	✓
Reg. Policy: Oil & Gas; Energy & Corruption	Q22-26	✓	✓	✓	✓	✓	✓	✓
Management: Sustain./ Maintenance	Q27-28	✓	✓	✓	✓	✓	✓	✓
LZC: Renewable energy use, inverter	Q29-31	✓	✓	✓	✓	✓	✓	✓

Study protocol also employed the use of neutrality techniques, prompts, probes and check questions during interviews. The issue of monitoring the interviewee's response to questions was critically dealt with by: identification of main issue and the priority being presented by the interviewee; listening for underlying logic; probing for inconsistency in individual opinion;

picking up and listening for clues from statements; putting responses into the context of the discussions; and noting down all non-verbal communications (Denscombe, 2014b).

## 5.5 ANALYTICAL TECHNIQUES

The study employed strategic combination of theoretical proposition, pattern-matching, and plausible rival explanation building in analysing case buildings' EEP. It aligned with the views of some authors (Stake, 1995; Yin, 2014) that, a prior knowledge based on theoretical propositions; plausible rival explanation based on formulating hypotheses; and the search for patterns and consistency within certain conditions, are strategies used in analysis of collected data. The study analysed case BEU and BEP. Both quantitative and qualitative analyses are used based on datasets on factors that affects BEP within and across-case buildings for the two groups.

### 5.5.1 Case Study Evidence on Energy Performance of Buildings (EPB)

Analyses of datasets are performed in case by case, and group bases. Case BEU analysis is done individually across the study buildings. Each building BEU, BEUI, BEC, BECI, CO<sub>2</sub> and CO<sub>2</sub>I are calculated and compared within a group and comparison between the two groups (Nigeria and UK). The normalised performance index (BEUI) is used to compare the EEP of the Nigeria's case buildings to the UK. Energy performance line (EPI) is used to compare case buildings within groups based on CDD and HDD. BECI is used to compare case buildings within and across the two groups based on normalised foreign exchange currency rate.

### 5.5.2 Quantitative Analysis: Descriptive and Non-Parametric statistics

The study used IBM SPSS22 to analyse parametric and non-parametric dataset; and the IBM AMOS 23, is used for performing the SEQM via collected data (Blunch, 2008).

The tests for internal consistency for measurement used for variables in all study's questionnaire surveys were performed using Cronbach's Alpha reliability test (George and Mallery, 2003). The Cronbach's alpha reliability test was carried out on measured constructs to determine their consistency and reliability of the expected results (Rachad, 2013). Its reliability coefficient normally ranges between 0 and 1; the closer it is to 1, the stronger the internal consistency of items measured in the scale (Gliem and Gliem, 2003).

The non-parametric test is based on chi-square; and is used to analyse the relationships and the interdependencies of the identified factors. Chi-square statistics, test of independence for more than two by two tables is used for cross tabulation. Also, the no specific direction for the relationship is adopted based on two-tailed tests of significance with level of significance: ( $\alpha$ ) = 0.05% ( $z = \pm 1.96$ ); 95% confidence level; and the degree of freedom (DF) =  $\{(R-1)(C-1)\}$  (Hinton, 2004).

It is therefore assumed that the level of significance ( $\alpha$ -value) is equal 0.05% ( $z = \pm 1.96$ ) at 95% confidence interval. In the case of the two categories (two by two tables), it is assumed that all the expected counts are at least 10; that is < than 10% of the cells should have expected counts less than 5. When it has more than two categories, it is assumed that not more than 20% of the cells have expected counts greater than 5. Nevertheless, more than 20% of study tests' cells have expected frequency count < than 5 for all the variables. This indicates that the necessary assumptions for the standard asymptotic calculation of the level of significance have been violated. Hence, use of likelihood ratio as the p-value for all the variables.

#### *I. Justification for using two different Likert Scales*

The current study adopted the Likert 5-point and 7-point scales to minimise bias associated with self-administered questionnaire response design in achieving an accurate data (Choi and Pak, 2005). Choi and Pak (2005) explained that the juxtaposed scales based on Likert ranking scales, allow for multi-response to a single question, which enable different responses rather than using separate scales. It allows respondents to think about issues deeper, but had been criticised for the potential of causing confusion amongst the less educated respondents.

The used of the two different Likert's ranking scales was founded on the need for the separation of complex technical issues that could only be comprehended by professionals, from general issues that all respondents could understand. This aligned with Krosnick and Alwin (1987, 1988), postulation that the level of education is a significant indicator of the degree of cognitive sophistication. Weng and Cheng, (2000), also argued that cognitive sophistication is relevant to response order-effects on ranking data; and could affect the response-order ratings on Likert-type scales. Thus, the relevance of cognitive sophistication was considered important for complex technical questions based on 7-point scales.



Validity, reliability, and discriminating power indices were also considered, as they are the most common criteria for choice of rating scale response category. Preston and Colman (2000 pp2), citing Miller's law, postulated that "the human mind has a span of apprehension capable of distinguishing about seven different items, which implies a limit of about seven on the numbers of categories that people are able to use in making judgements about the magnitude of unidimensional stimuli". They argued that most researchers favoured the seven-point scales as it helps to maximise reliability and increase inter-item consistency; while few supported the use of the 5-point rating scales because it has higher reliability based on objective measures of original stimuli.

Preston and Colman (2000), findings confirm the favourable position of the 7-point scales; and advised that internal consistency does not differ significantly, but test re-test reliability decreases for scales more than 10 response categories. They concluded that scientific findings give more support for the 7-point scales than the 5-point scales, which seems to have less justification for its popularity. Whilst, suggested that the 5-point scales are better when face validity is paramount; and to prevent respondents from being frustrated and demotivated as 5-point scales are perceived to be easier and quicker to use than the 7-point scales.

### 5.5.3 Qualitative Analysis

Study adopts thematic analysis in analysing responses from interviews. Extant literature (Bryman, 2016), describes it as a research focus process of identification of category, and building on coding identification in collected data. It provides a basis for theoretical understanding of data with view of making theoretical contributions to study literature.

The audio recorded interviews were transcribed verbatim, formatted manually using Microsoft words, and imported into NVivo10 software for data analysis. The qualitative software (NVivo10) is used to code the responses on thematic basis (Bryman, 2016). Relevance information that support research questions is identified under each theme (Bazeley, 2013).

Thereafter, evaluation coding method (Saldaña, 2009), is employed for coding participants' responses under the seven contextual factors of study theoretical framework as parent nodes. Whilst, all specific responses (as reflective indicators), under the eight contextual variables

were coded as child nodes. Also, cluster analysis is used for word frequency query in obtaining pattern and relationships.

#### 5.5.4 Structural Equation Modelling- SEQM

SEQM-based multivariate regression analysis is used to investigate the relationship between several factors that affects BEP (Hinton, 2004). It helps to examine the plausibility of study theoretical model, which could explain the relationship amongst contextual variables (Hu, 1997). The analysis helped in the investigation of several factors that constitute SMB for improving BEP. The correlation between these factors could indicate causal relations, and might arise due to other exogenous (third) factors. Hence, the SEQM-based multivariate analysis is used in identifying possible causal relationships and co-axial associations (correlations) amongst critical factors that propels BEE (Blunch, 2008).

##### *I. Procedures for SEQM Analysis*

The standard protocol for the SEQM have been expounded by various authors (Blunch, 2008; Le Dang et al., 2014; Hou et al., 2014), in extant literatures. The current study SEQM procedure involves a two-step approach, namely: the measurement model validation that addresses the affiliations between the latent and the measurement (manifest) variables; and the structural model that describes the causal relationship amongst the latent variables.

The IBM AMOS 23, was used for performing SEQM for the current study (Blunch, 2008). SEQM was used to examine and define the structural relationship using maximum likelihood estimation parameter. Based on Blunch's hypothesis of causal structure, models can be depicted in two ways either: as a graphical representation with variables shown as circles (or eclipses) and squares (rectangles), possible causal links (as arrows), and covariance (as two-headed arrows); or as a system of equations that can be used for algebraic manipulations. The current study adopted the graphical method because of its strong communicative force. Whilst, the procedure undertaken (Blunch, 2008) is further reviewed (in Appendixes 8A-8H).

##### *II. Model Fit Indices*

There are divergent views on acceptable minimum criteria for model fit indices, several studies have different threshold for model best fits. Hence, the need for standardised metrics for reporting model fit including associated thresholds. Current study therefore formulated a fit

threshold table based on best practice across previous studies. The threshold table was designed based on the combination of recommendations from several authors (Blunch, 2008; Hair et al., 2010; Gaskin, 2012), as illustrated in the below:

The threshold table was designed based on the combination of recommendations from several authors (Ibid), as illustrated in the below:

Table 5:7: SEQM- Model Fit Criteria and Acceptable Interpretation

MODEL FIT CRITERIAL AND ACCEPTABLE FIT INTERPRETATION		
MODEL FIT METRICS	GREAT THRESHOLD	ACCEPTABLE THRESHOLD
Chi-Square/df (CMIN/DF)	1 - 3	< 5
P-Value for the Model	> .05	-
RMR (Root-Mean-Square- Residual)	< .05	< .09
CFI (Comparative Fit Index)	> .95	> .80
GFI (Goodness of Fit)	> .95	> .90
AGFI (Adjusted Goodness of Fit)	> .95	> .80
RMSEA (Root-Mean-Square Error of Approximation)	< .05	.05 - .10
PCLOSE	> .05	-
NFI (Normed Fit Index)	> .92	> .90
RFI (Relative Fit Index)	> .90	-
IFI (Increment Fit Index)	> .90	-
TLI (Trucker Lewis Index)	value close to 1	-
PRATIO: PNFI; PCFI; and PGFI	Values > .60	-

Standardised factor loading, average variance extracted (AVE) and construct reliability (CR) were used for construct validity for all study models. The factor loading (FL) size of all observed variables indicate their strength on the associated constructs. FL represent the relationship between a factor and its indicator. This also contribute to construct validity as FL below 0.50 are considered weak and unacceptable (Hair et al., 2010). The measurement error signifies other variation for an observed variable. Also, CR indicates convergent validity and CR at 0.70 and above point to a good reliability (Le Dang et al., 2014). While AVE is also an indicator of convergent validity, and a value > 0.50 suggests adequate convergence (Hair et al., 2010).

### III. Bootstrap

The Bollen-Stine is used in testing study models as whole based on bootstrapped  $\chi^2$ - tests for testing hypotheses to find out if models are ‘100pct’ correct (Bollen and Stine, 1993; Blunch, 2008). The more a Bollen-Stine’s p-value get close 1.0, the more its model indicates increases in perfect fit.

## 5.6 SUMMARY

The section established research design as a plan, whilst research methods involved the procedure and tools for collecting data and its analytical techniques. The chapter illustrated how pilot study was conducted for potential case buildings but its results were unutilised. The physical walk-through and the use of OST including its weighting application were also explained. Whilst, the purpose and protocol for the second study BEU survey based case buildings was well described.

Third study, quest-surv1 was a POE used for ten case buildings located in Nigeria and the UK. It was used to seek users' perspective building comfort and on BEP. While, the fourth study, quest-surv2, was conducted for professional FMs outside case buildings for triangulation purpose. Also, the fifth study, quest-surv3 was for model validation based on SEQM analysis.

The reasons for the adoption of SEQM and its analytical procedure were expounded upon. Finally, the sixth study, interv-surv4, was an interview conducted for FMs and owners of case buildings. Reports were used for triangulations and possible confirmation of rival explanation to use for cross-case conclusion and model validation.

## 6 Chapter Six: Energy Performance of Case Buildings

### 6.1 INTRODUCTION

This chapter presents the detailed profiles, and EEP of case buildings measured with study's PMs underpinned by the principles of sustainability (environment, social and economic). Besides, it used selected KPIs based on these principles in comparing the operation of study buildings within cases and a cross-cases. Furthermore, the normalised performance index (NPI), and energy performance line (EPL) of cases were calculated for benchmarking across countries. The EPL is used in examining how changes in weather conditions affect case BEP.

### 6.2 NIGERIA CASE BUILDINGS' PROFILE

The Nigeria case buildings are situated in Lagos, southwest Nigeria (in Appendix 10), and are:

- the Arup & Partner head-office tower, owned by Mulleck Nominees Ltd., (ID101) ~ GPS coordinate 60 26' 47" N 30 24' 17" E of the Greenwich Meridian (GM);
- Centre of Greatness (COG), zonal head-office, zone 5, province 23, Lagos, of the Redeemed Christian Church of God (ID102); ~ GPS coordinate, 60 38' 40" N 30 22' 18" E (GM);
- Miviti Communications Ltd office building (ID103) ~ GPS coordinate, 60 38' 32" N 30 22' 13" E (GM);
- Centu-Serve head-office building (ID104) ~ GPS coordinate 60 39' 18" N 30 18' 33" E (GM); and
- Cornices Consult Ltd., head-office owned by Mods Holding Ltd., (ID105) ~ GPS coordinate, 60 36' 3" N 30 21' 10" E (GM).

The detailed profile and operational hours of these five case buildings are illustrated in Table 6:1 and Table 6:2 as follows:

Table 6:1: Profile of Nigeria Case Buildings

Profile of investigated buildings in Lagos, southwest Nigeria

Building Identity	Location	GIA (m <sup>2</sup> )	Storey Heights	Building Type	Uses	Completion Year	Refurbished Year	HVAC	Power Sources
Bldg101	Lagos	1306	7	Commercial	Office	1977	2007	2Nrs. Passenger Lifts, Split Unit AC	Grid Electricity & 2Nrs. Generators (325kVa & 60kVa)
Bldg102	Lagos	556	2	Domestic	Worship Centre & Office	1999	2013	Split Unit Air-conditioners	Grid Electricity & 2Nrs. Generators (60 & 5kVa)
Bldg103	Lagos	1220	2	Domestic	Dwelling & Office	1995	N/A	Split Units AC & Fans	Grid Electricity & 8Nrs. Generators (3.5- 7kVa)
Bldg104	Lagos	864	3	Commercial	Office	1993	N/A	Split Units AC & Fans	Grid Electricity & 6Nrs. Generators (3.5- 7kVa)
Bldg105	Lagos	1398	4	Commercial	Office	1987	N/A	1Nr. Passenger Lift, Split Units AC & Fans	Grid Electricity & 20Nrs. Generators (3.5- 7kVa)

Table 6:2: Operational Hours of Nigeria Case Buildings

NIGERIA CASE BUILDINGS' OCCUPANCY HOURS				
Bldg. ID	No. of Staff	Staff Hours	Addition Users' Hours	Annual Occupancy Hours
101	85	141,440	-	141,440
102	7	11,648	62,400	74,048
103	52	37,856	-	37,856
104	52	86,528	-	86,528
105	59	98,176	-	98,176

The details of technical, construction and physical properties of each case buildings are summarised (Appendixes11-15).

### 6.3 UK's CASE BUILDINGS' PROFILE

The UK case study buildings are owned by Anglia Ruskin University, and managed by the Facilities & Estate department. They are situated on Anglia Ruskin University's Chelmsford Campus, in southeast England (in Appendix16) are:

- Marconi building (ID206) ~ GPS coordinate 51° 44' 34"N 00° 28' 22"E (GM)
- Postgraduate Medical Institute (PMI) (ID207) ~ GPS coordinate 51° 44' 41"N 00° 28' 24"E (GM)
- Mildmay building (ID208) ~ GPS coordinate, 51° 44' 36"N 00° 28' 22"E (GM)
- Tindal building (ID209) ~ GPS coordinate 51° 44' 36"N 00° 28' 21"E (GM); and
- Michael Ashcroft building (ID210) ~ GPS coordinate 51° 44' 30"N 00° 28' 27"E (GM).

These case buildings (*Table 6:3* and *Table 6:4*) are educational buildings with detailed profiles and operational hours as thus:

Table 6:3: Profile of UK Case Buildings

Profile of investigated buildings in Chelmsford, Essex southeast England

Building Identity	Location	GIA (m <sup>2</sup> )	Storey Heights	Building Type	Uses	Completion Year	Refurbished Year	HVAC	Power Sources
Bldg206	Chelmsford	5351	4	Educational	Office/lecture	2008	N/A	2Nrs. Lifts, mech. Ventilation, Heating boiler	Grid Electricity
Bldg207	Chelmsford	2639	4	Educational	Office/lecture	2011	N/A	2Nrs. Lifts, Heating boiler	Grid & Gas Electricity
Bldg208	Chelmsford	975	1	Educational	Sport & Office	2005	N/A	Heating boiler	Grid & Gas Electricity
Bldg209	Chelmsford	2475	4	Educational	Office/lecture	2005	N/A	2Nrs. Lifts, Heating boiler	Grid & Gas Electricity
Bldg210	Chelmsford	3723	4	Educational	Office/lecture	2003	N/A	2Nrs. Lifts, Heating boiler	Grid & Gas Electricity

Table 6:4: Operational Hours of UK Case Buildings

UK CASE BUILDINGS' OCCUPANCY HOURS				
Bldg. ID	No. of Staff	Staff Hours	Addition Users' Hours	Annual Occupancy Hours
206	86	143,104	28,377	171,481
207	61	101,504	1,502	103,006
208	3	4,992	43,005	47,997
209	57	94,848	-	94,848
210	64	106,496	17,008	123,504

The details of technical, construction and physical properties of UK case buildings are summarised (in Appendixes17-21).

#### 6.4 CASE BUILDINGS' SURVEY

The operational sustainability tool (OST) ranking was used during the technical survey of the case buildings. A weighted percentage (formula14) is applied to get individual percentage score. The case buildings' result of the two groups revealed initial assessment based on

operational issues (in Appendix9). The result of the Nigeria's case buildings was ranked as: Bldg101 (21.3%) fair, Bldg102 (14.8%) poor, Bldg103 (9.3%) poor, Bldg104 (11.1%) poor, and Bldg105 (8.3%) poor.

All the UK case buildings scored: Bldg206 (77.3%), Bldg207 (80.9%), Bldg208 (81.8%), Bldg209 (82.7%) and Bldg210 (82.7%), obtained excellent ranking ( $\geq 70.0\%$ ), as they are managed by the same estate & FM department. Finally, the OS result indicates the following categories for the case buildings: Bldg101 ('D'), Bldg102 ('E'), Bldg103 ('E'), Bldg104 ('E'), and Bldg105 ('E'), whilst, all the UK case buildings falls within the OS category 'A'.

## 6.5 CASE BUILDINGS SUMMARY

Most of the Nigeria case buildings were built between 1993 and 1995 except for bldg105 that was built in 1987. Also, they are commercial and domestic buildings of 2-7 storey heights, with bldg101 having the highest height (7- storey). Their GIA lies between 556m<sup>2</sup> (bldg102), and 1395m<sup>2</sup> (bldg105). Whilst, their annual occupancy hours lie between 37, 856hrs (bldg103) and 141,440hrs (bldg101). All the Nigeria buildings are equipped with air-conditioners and generators, however, they lacked BEMS, BMS meters and other energy saving devices.

The UK case buildings were built between 2005 and 2011. They are mostly academic and office buildings of 3-4storey heights, except bldg209 (sport hall) that is a single storey height. Their GIA lies between 975m<sup>2</sup> (bldg208), and 5351m<sup>2</sup> (bldg206). The annual occupancy hours lie between 47, 997hrs (bldg208) and 171,481hrs (bldg206). The UK case buildings are fitted with lifts, HVAC, BEMS and other control technologies

The case study buildings' OS was surveyed based on the study's OST. The OS result revealed that the Nigeria buildings are poorly managed with the least rating ('E'), except for Bldg101 ('D') that is fairer. Whereas, the UK case buildings initial result indicates better management as they fall within the highest OS category 'A'.



## 6.6 CASE BUILDINGS' ENERGY PMs AND KPIs

The study used BEU, BCO<sub>2</sub> emissions and BEC to measure social (comfort), environmental and economic performance of case buildings. The data collected indicates how selected case buildings perform based on study equations (1, 2 and 4) in section 4.7.1. Similarly, current study's KPIs are used in measuring the BEP of case study buildings for performance standardisation and comparison within each country. BEUI, BCO<sub>2</sub>I and BECI are applied as factors of case BEP based on study equations (5, 6 and 7) in section 4.7.2.

The collated energy consumption data for Nigeria and the UK case buildings were analysed based on metered bills, estimated bills, and invoices for diesel and PMS (used in fuelling generators). Individual case analysis was used in categorising cases based on study's PMs (BEU, BCO<sub>2</sub> emissions and BEC), and their KPIs (BEUI, BCO<sub>2</sub>I and BECI), using study equations and energy sources. Also, a line plot time-series energy monthly data were used in comparing BEU trends accordingly.

Case buildings' BEU and BEUI were used in measuring energy performance for comfort and operations for the period (2011-2014) under review. Table 6:5 and Figure 6.1 present the energy consumption status of case buildings in kWh/year (BEU) and kWh/m<sup>2</sup>/year (BEUI).

Table 6:5: Nigeria-UK Case Study's BEU per Annual

<i>Nigeria- UK case study buildings' energy used per annual (kWh/yr.)</i>										
<i>Year</i>	<i>Bldg101</i>	<i>Bldg102</i>	<i>Bldg103</i>	<i>Bldg104</i>	<i>Bldg105</i>	<i>Bldg206</i>	<i>Bldg207</i>	<i>Bldg208</i>	<i>Bldg209</i>	<i>Bldg210</i>
2011	1,483,775	38,474	57,372	118,173	198,372	896,971	769,750	146,319	526,746	371,156
2012	852,957	36,847	52,140	93,995	139,426	1,081,674	942,516	145,622	554,302	630,049
2013	796,521	38,243	46,781	77,306	140,775	1,097,088	957,128	141,718	569,542	687,004
2014	1,075,159	57,108	48,376	95,490.00	140,694	1,159,014	893,006	120,115	517,708	458,272

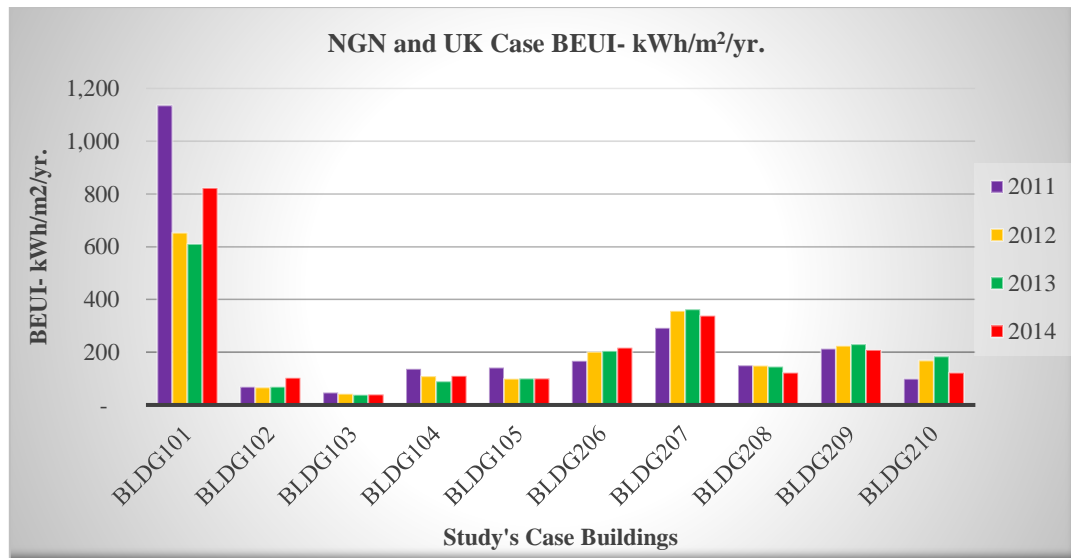


Figure 6.1: NG-UK Case Buildings' BEUI

Further analysis of buildings' energy sources and percentage share is illustrated using Table 6:6 and Figure 6.2. They revealed annual percent share of grid electricity and fossil-fuel electricity. The fossil-fuel comprised of diesel and PMS for powering generators used in the Nigeria's buildings, and gas-electricity used in the UK's buildings. It helps in determining its impacts on overall BEP.

Table 6:6: NG-UK BEU: % Share of Energy Sources

Nigeria and UK Case Study Buildings' BEU: % Share of Energy Sources										
BEU: Energy source (%)	Bldg101	Bldg102	Bldg103	Bldg104	Bldg105	Bldg206	Bldg207	Bldg208	Bldg209	Bldg210
2011 Grid Electricity	11.5	19.1	16.3	24.7	24.8	100.0	62.0	70.3	53.2	42.0
2011 Fossil Fuel	88.5	80.9	83.7	75.3	75.2	0.0	38.0	29.7	46.8	58.0
2012 Grid Electricity	5.9	19.1	16.3	9.1	4.4	100.0	60.0	67.5	49.8	10.1
2012 Fossil Fuel	94.1	80.9	83.7	90.9	95.6	0.0	40.0	32.5	50.2	89.9
2013 Grid Electricity	10.9	10.5	23.2	10.1	3.9	100.0	59.5	67.8	48.7	15.3
2013 Fossil Fuel	89.1	89.5	76.8	89.9	96.1	0.0	40.5	32.2	51.3	84.7
2014 Grid Electricity	15.0	10.3	29.9	12.6	3.7	100.0	66.6	78.9	53.7	33.0
2014 Fossil Fuel	85.0	89.7	70.1	87.4	96.3	0.0	33.4	21.1	46.3	67.0
Fossil Fuel Type	Diesel	Diesel & PMS	Diesel & PMS	PMS	PMS	Nil	Gas-elect	Gas-elect.	Gas-elect.	Gas-elect.

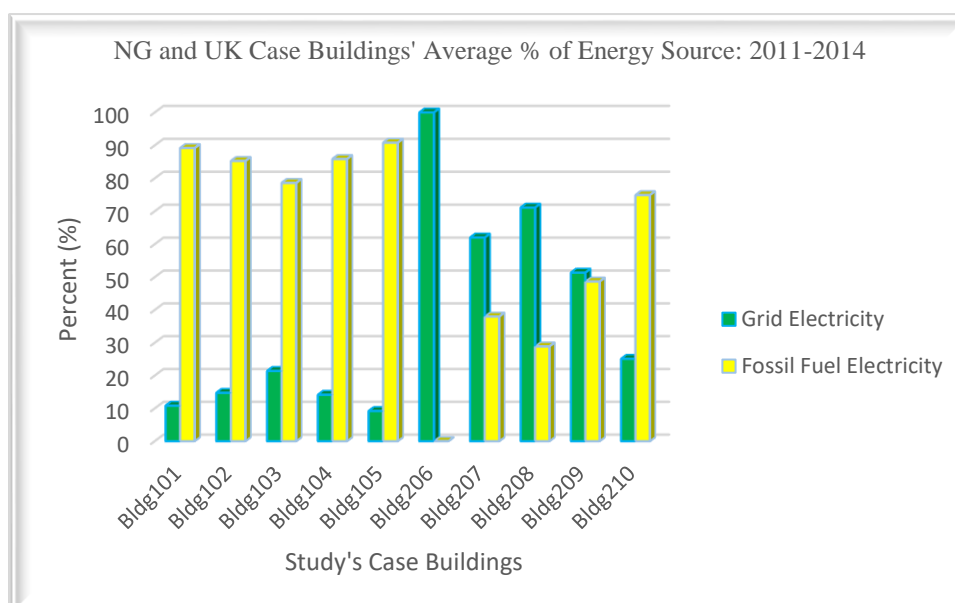


Figure 6.2: Average % NG-UK Case Buildings Energy Source

Likewise, Table 6:7 and Figure 6.3 shows the analysis of case buildings' CO<sub>2</sub> emissions (KgCO<sub>2</sub>e/yr.) and its intensity (KgCO<sub>2</sub>e/m<sup>2</sup>/yr.). The CO<sub>2</sub> emissions from case buildings is calculated based on fuel-type calorific value and carbon emission factor for Nigeria and UK.

Table 6:7: NG-UK Case Buildings' Annual CO<sub>2</sub> Emission

<i>Nigeria- UK Buildings' Case Study- Carbon Emission per Annual (KgCO<sub>2</sub>e/yr.)</i>										
<i>Year</i>	<i>Bldg101</i>	<i>Bldg102</i>	<i>Bldg103</i>	<i>Bldg104</i>	<i>Bldg105</i>	<i>Bldg206</i>	<i>Bldg207</i>	<i>Bldg208</i>	<i>Bldg209</i>	<i>Bldg210</i>
2011	345,032	10,309	16,780	30,091	54,198	456,558	285,403	59,604	178,626	84,363
2012	219,046	9,528	7,462	30,121	46,627	550,572	346,572	57,207	179,096	132,283
2013	191,412	10,198	7,140	21,319	53,103	558,418	351,728	56,209	181,286	142,952
2014	280,398	14,444	7,236	30,940	52,718	589,938	349,842	51,528	169,957	99,416

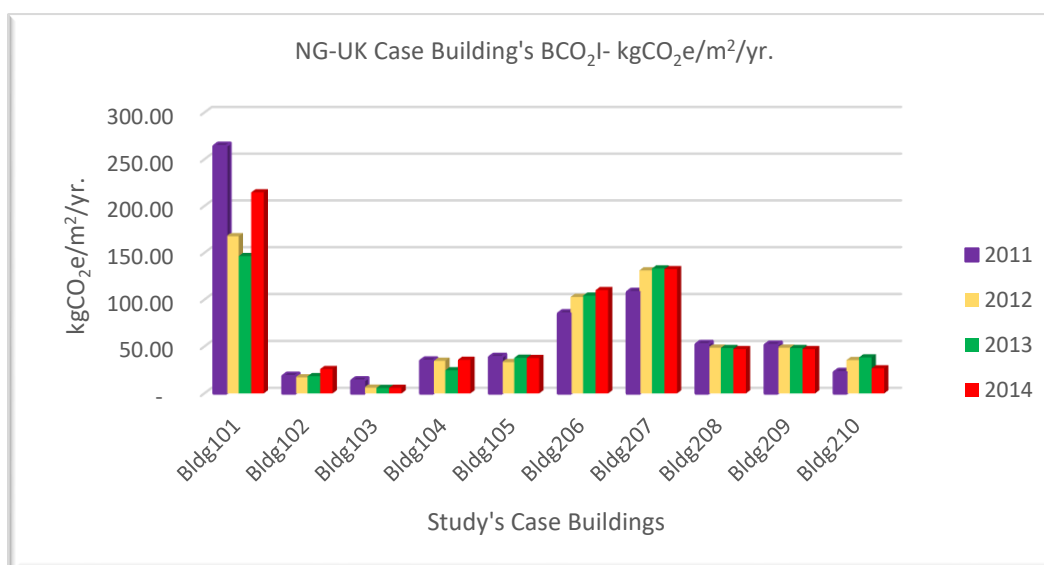


Figure 6.3: Nigeria-UK Case Buildings' BCO<sub>2</sub>I

Case buildings, energy cost (BEC) and its intensity (BECI) analysis are analysed and evaluated in Table 6:8 and Figure 6.4. The unit of cost for energy used in study's case buildings is normalised with the official exchange rate of the Nigeria Naira to the British Pound Sterling (CBN, 2015). It was useful in determining the economic performance of buildings in Nigeria compared to the UK.

Table 6:8: NG Case Building BEU Cost per Annual.

Nigeria- UK Case Study Buildings' Energy Cost per Annual (£/yr.)										
Year	Bldg101	Bldg102	Bldg103	Bldg104	Bldg105	Bldg206	Bldg207	Bldg208	Bldg209	Bldg210
2011	66,336.39	1,673.75	1,230.00	2,587.12	5,455.19	116,695.92	69,665.11	14,775.84	42,894.72	18,336.38
2012	40,295.03	1,757.44	1,303.70	3,515.57	5,613.30	140,725.81	84,473.50	14,100.06	42,596.69	27,996.53
2013	35,284.48	1,852.39	1,633.25	3,456.25	8,721.52	142,731.18	85,721.00	13,875.45	42,984.70	30,158.16
2014	50,041.68	2,759.11	1,727.52	4,768.45	8,534.70	150,787.77	86,188.07	21,279.86	40,553.40	21,279.86

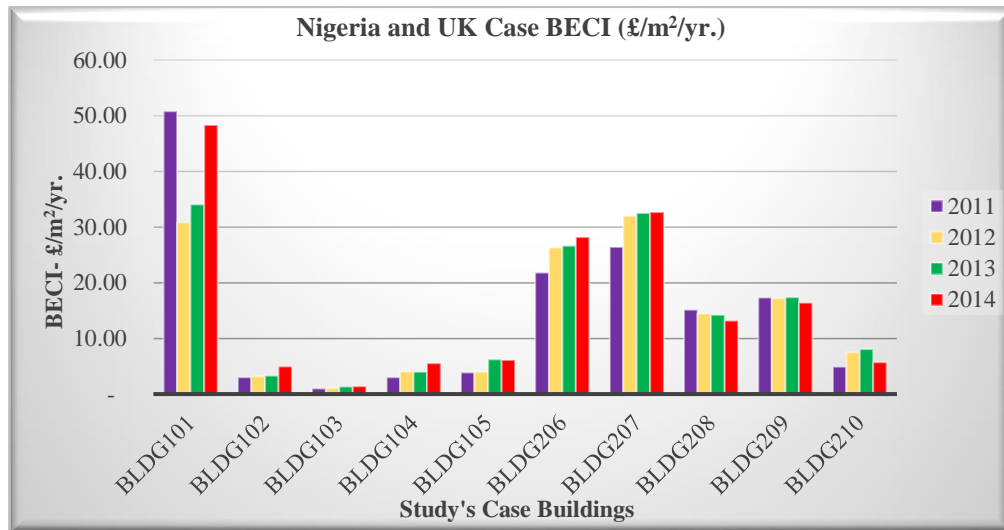


Figure 6.4: NGN-UK Case Buildings' BECI

#### 6.6.1 Case buildings' Energy Used Trend

A line Plot time-series was used to investigate the general trend of monthly BEU without normalisation. The results, as indicated (*Figure 6.5*, *Figure 6.6* and *Figure 6.7*), reveals the contrast across cases for Nigeria and the UK. Although each case has a different pattern of BEU, but the Nigeria cases showed irregular non-cyclical patterns compared to the UK cases that indicated cyclical patterns. The line plot was used for analysing BEU trends and not for predictions, as the line plot cannot be used to disaggregate base load performance.

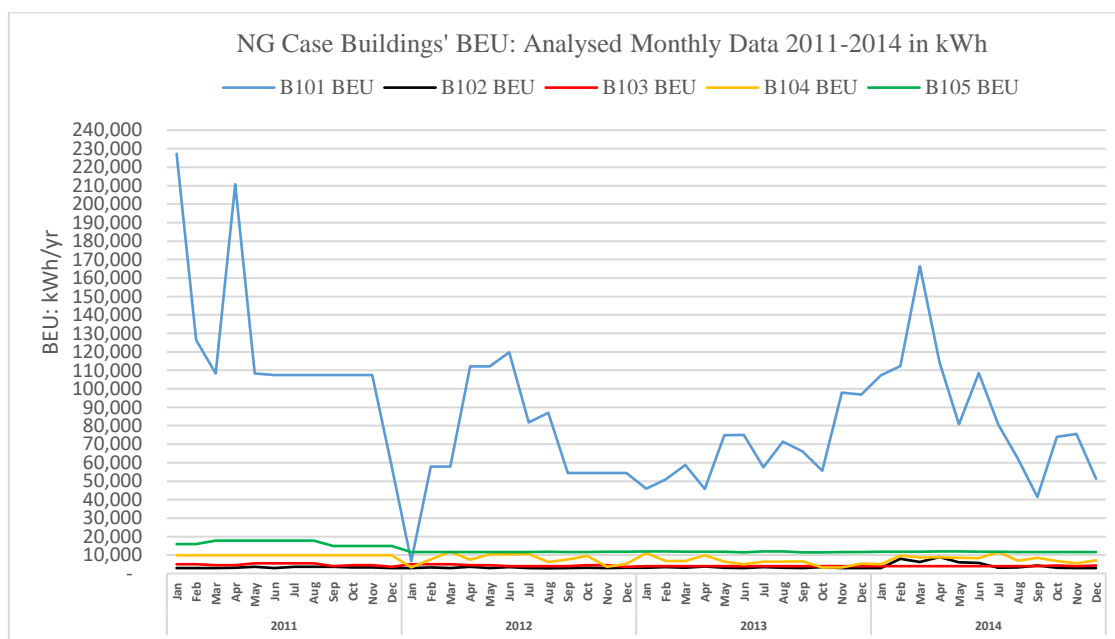


Figure 6.5: NG Case Buildings' Monthly BEU Data (line plot)

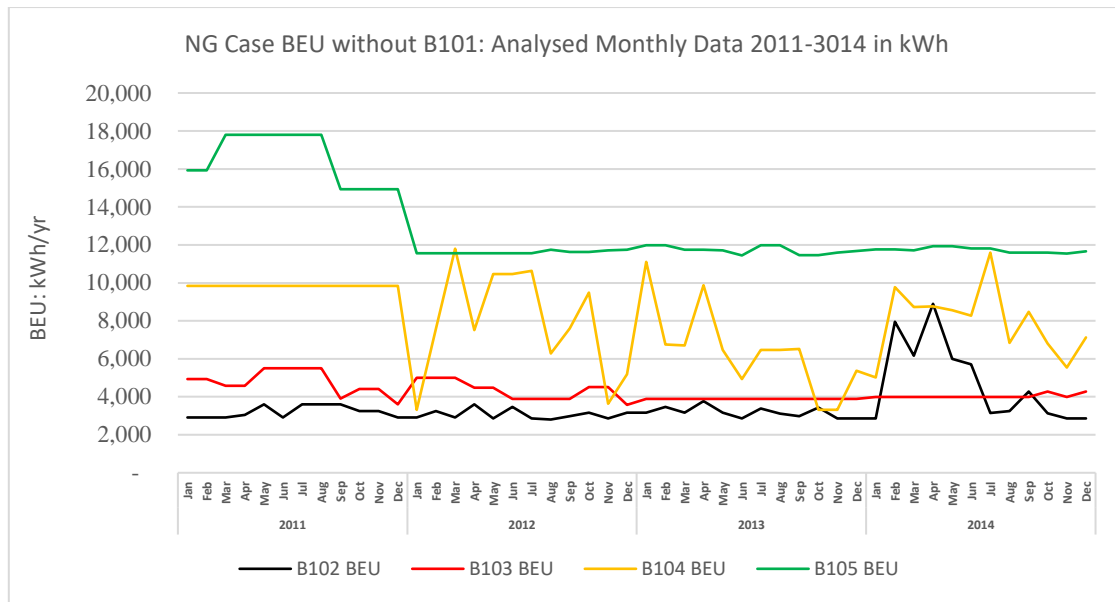


Figure 6.6: NG Case Buildings' Monthly BEU Data (without Bldg101)

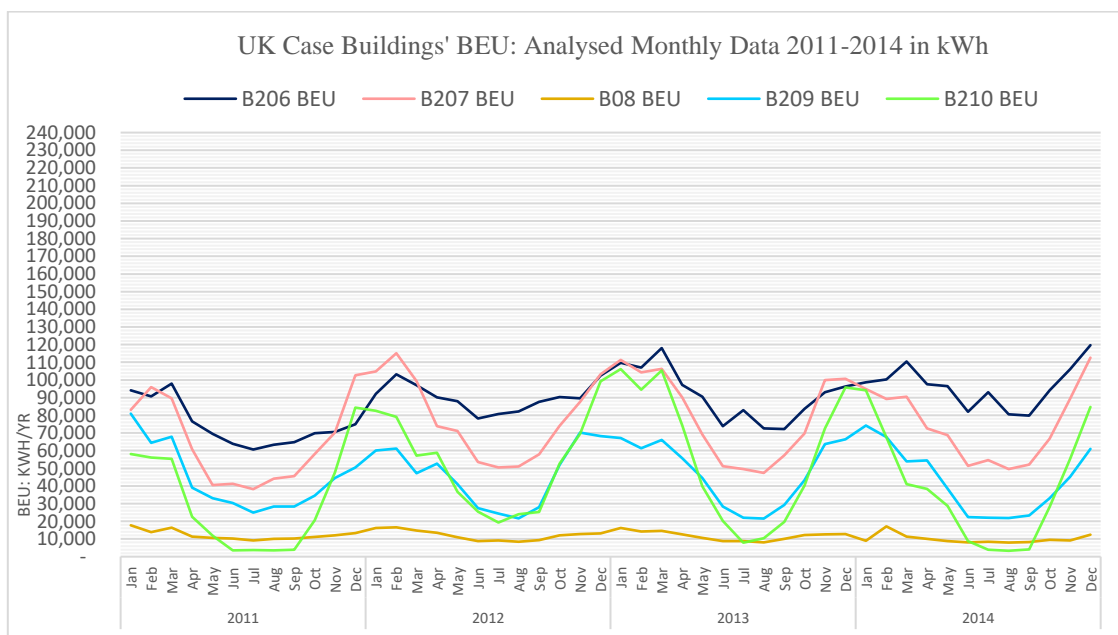


Figure 6.7: UK Case Buildings' Monthly BEU Data (line plot)

The Nigeria case buildings' analysis revealed that bldg101 (1,306m<sup>2</sup> GIA- gross internal area), (Figure 6.5), had undefined pattern of BEU. Its monthly BEU range varies from 169,400kWh (in 2011) to 124,978kWh (in 2014). In 2011, Bldg101 BEU peaked at 227,279kWh in January and dropped to 107,446kWh by November/ December. It strongly indicates irregular consumption pattern that defies external weather variations. Also, revealed a 73.4% variance between 2011 and 2014. It could be observed that its BEU clustered for the months of June to

November 2011 at 107,446kWh. Obviously, it's BEU of 227,290kWh (January 2011) and 210,835kWh are outliers for likely reasons of double entries for fuel invoices. Hence, another line-plot (Figure 6.6), was created for clarity of other cases' trend. However, removing the outliers reduced variations to 119,774kWh/yr. (2011-2014) overall ranges.

Case bldg102 (GIA 556m<sup>2</sup>) BEU indicated a better energy performer (Figure 6.6). Its BEU showed an increasing trend for the same period. It uses both grid and PMS (premium motor spirit) for generator-powered electricity. Its monthly BEU followed a slightly flatten seasonal and cyclical pattern, and a surge in BEU between January and June 2014. Further analysis reveals a range of 20,260kWh/year at 43% variance for the case (for 2011-2014).

The BEU of Bldg103 (GIA 2,722m<sup>2</sup>), had a decreasing trend from 57,372kWh (in 2011), to 48,376kWh (in 2014). The monthly time-series line plot (Figure 6.6), reveals, flatten and regular but slightly seasonal pattern. The pattern of its BEU is like Bldg102 with similar type of energy sources and billing system.

Bldg104 (GIA, 864m<sup>2</sup>) BEU examination, revealed a decreasing trend from 118,173kWh/year (in 2011) to 95,490kWh (in 2014). The BEU pattern is like that of cases bldg102. It's time series line plot (Figure 6.6), reflects irregular seasonal and non-cyclical pattern. However, metered billing method was used for the year 2012-2014 except for 2011, where a flatten pattern was recorded. The flatten pattern observed is as a result of the adopted billing method in 2011.

The BEU data for bldg105 (1,398m<sup>2</sup> GIA) shown in Error! **Unknown switch argument.**, also indicate increased with an overall range of 58,946 at 41.9% variance. In 2011, the BEU time-series has a seasonal downward trend, but subsequently (from 2012-2014), the trend change to a flat pattern for its monthly BEU. Investigation revealed the use of metered billing (in 2011) and estimation billing method (for 2012-2014) for the building at different time. Hence, the two patterns shown could be underpinned by metered bills and PMS-fuelled electricity usage at.

Amongst the UK buildings (Figure 6.7), Case bldg206 (with 5,351m<sup>2</sup> GIA), consumed the highest electrical energy with overall range of 56,290kWh/yr., (2011-2014). The analysis indicates an upward trend in its BEU pattern as revealed in the line plot. Its trend is slightly

cyclical with a shallow trough compared to others. Also, the BEU result shows annual variances of: 33,527kWh (2011) and 39,104kWh (2014) that indicted possible response to weather variations.

The pattern of BEU for Case bldg207 (GIA, 2,639m<sup>2</sup>), reveals an increasing trend with regular seasonal and cyclical patterns (Figure 6.7). On the overall average, it used 890,600kWh/year, with a range of 126,255kWh/year and about 16.4% variance (for 2011-2014). This displays steeper peak and trough than Bldg206, which indicates likely greater response to variations in weather.

Case bldg208 BEU trend presented (Figure 6.7), indicated a regular seasonal and cyclical pattern with a decreasing trend. Bldg208 BEU decreases over the period with a range of 26,204kWh and 19% variance (during 2011-2014). This might be due to its occupancy hour and use type.

The trend performance of bldg209 (GIA, 2,475m<sup>2</sup>) (Figure 6.7), indicates that its BEU was moderate and stable; and had regular seasonal trend with cyclical patterns. Its BEU had the lowest range of 9,039kWh/year at just 2% variance over the study period (2011-2014). Thus, making it BEU the most predictive when compared across cases.

Bldg210 (GIA, 3,723m<sup>2</sup>) analysed BEU trend performance (Figure 6.7), showed a regular season and cyclical pattern with an increasing trend. However, its BEU variation is significant at 59% over the study period. This resulted in an average BEU of 536,620 kWh/year with the largest BEU range of 315,848 kWh/year amongst case buildings.

#### 6.6.2 Case Buildings' Energy Performance

Generally, the comparison of case buildings' EEP indicates that the Nigeria buildings except bldg101 performed fairly compared to the UK buildings. The BEP variability in *Table 6:9*, reveals that bldg101 was the poorest amongst the ten buildings, as it has the highest average BEUI (806kWh/m<sup>2</sup>/yr.), with the highest variation in the period. Consequently, it earned the highest carbon footprint (198kgCO<sub>2</sub>e/m<sup>2</sup>/yr.) and the most expensive (£41.00/m<sup>2</sup>/yr.).



Table 6:9: NG-UK Case Study Buildings' BEP Variability and Energy Sources

Nigeria and UK Case Study Buildings' BEP Variability (via PMs & KPIs) and % Share of Energy Sources										
Study Period: 2011-2014	Bldg101	Bldg102	Bldg103	Bldg104	Bldg105	Bldg206	Bldg207	Bldg208	Bldg209	Bldg210
GIA (m <sup>2</sup> )	1306	552	2722	864	1398	5351	2639	975	2475	3723
BEUI (kWh/m <sup>2</sup> /yr.): Ave.	806	77	42	111	111	198	338	142	219	144
BEUI: Variance (%)	65	1	58	43	37	25	8	19	10	59
BCO <sub>2</sub> I (kgCO <sub>2</sub> e/m <sup>2</sup> /yr.): Ave.	198	20	8	33	37	101	126	49	49	31
BCO <sub>2</sub> I: Variance (%)	65	40	138	3	15	25	18	11	9	48
BEC (£/m <sup>2</sup> /yr.): Average	41.00	3.61	1.21	4.15	5.07	25.74	30.89	14.26	17.08	6.57
BEC: Variance (%)	65	45	34	53	36	29	20	14	6	48
Energy Source %: Grid-elect.	11	17	27	14	9	100	62	71	51	25
Energy Source %: Fossil fuel	89	83	73	86	91	0	32	29	49	75

Bldg102, had a better energy use performer as revealed in the table. Case bldg104 and bldg105 performances are moderate, simply the case bldg104 despite being smaller in size than bldg105, exhibit the same BEU intensity (111kWh/m<sup>2</sup>/yr.) with it. Therefore, it can be less efficient than bldg105. Case bldg103 has the lowest BEUI and BCO<sub>2</sub>I compared across cases. This could result from several factors like, use of buildings, use of generators of smaller capacity, and operational hours. Case bldg103 is the cheapest (£1.21/m<sup>2</sup>/yr.) amongst the ten buildings.

Case bldg207 is the worst performing building in terms of social, environmental and economic performance within the UK's buildings; and the next poorest across cases. The building has higher BEUI (338kWh/m<sup>2</sup>/yr.) despite being smaller than case bldg206 and bldg210. Although bldg206 consumes high kWh of electricity, however, its performance improved after normalisation factor is applied. The building performed better than bldg207 & 209. Bldg206 (101kgCO<sub>2</sub>e/m<sup>2</sup>/yr.) was the second largest emitter after bldg207 (126 kgCO<sub>2</sub>e/m<sup>2</sup>/yr.). Case bldg206 BECI is regular as it has regular pattern (20% variance) of expense, and it is powered only with grid electricity.

The performance of bldg208 (142kWh/m<sup>2</sup>/yr.) and bldg210 (144kWh/m<sup>2</sup>/yr.) are comparatively better than other UK's buildings based on BEUI. However, bldg210 is more efficient since it had the lowest BCO<sub>2</sub>I (31kgCO<sub>2</sub>e/m<sup>2</sup>/yr.), and larger than bldg208 in size. While bldg209 BEUI (9% variance) is the most predictive when compared across cases. It indicated a good environmental performance, and stable energy performance amongst cases

Finally, the Nigeria buildings are associated with fossil-fuel based generators for electricity generation, and their energy sources indicated at least 73% reliance on fossil-fuel. The UK buildings have more reliance on grid-electricity and supplemented with grid-gas supplies. It was found that bldg210 has, the cheaper BECI (£6.57/m<sup>2</sup>/yr.), mainly to its energy source (gas-electricity) and cost of natural gas. Thus, analysis confirms Bldg210 as the best environmental performing building across cases.

## 6.7 NORMALISED PERFORMANCE INDEX

Benchmarking across countries is achieved based on NPI using study equation9 (section 4.7.2). After adjusted for weather, there was a slight decrease in BEU for the Nigeria cases whilst, that of the UK buildings increased slightly. Subsequently, the ten case buildings are benchmarked against the CIBSE TM46 (2008) typical office consumption (electricity typical- 95kWh/m<sup>2</sup>, and fossil thermal typical- 120 kWh/m<sup>2</sup>). A typical application of the NPI is indicated in Table 6:10.

Table 6:10: NPI for case Bldg101 BEUI

Example of an NPI Calculation: Nigeria and UK Case Buildings					
NG Case Building	2011	2012	2013	2014	Average
Bldg101 BEUI:	1,136	653	610	823	806
Actual CDDs	2867	2820	2856	2955	
Ave. CDDs	2653	2653	2653	2653	
NPI for Bldg101	1051	614	567	739	743

### 6.7.1 Nigeria and UK Case Buildings' Benchmarking

CIBSE TM46 BEUI benchmark of 215 kWh/m<sup>2</sup> (for typical office buildings), is used for benchmarking case buildings' NPI. It became clearer that building typology have impact on level of BEU and hence level of performance (Figure 6.8). The study's five sub-categories of office-type (namely: office-use-only, office-domestic-use, office-religion-use, office-sport-use, and office-educational-use), indicates different performance levels. However, overall result indicates that bldg101 performance is still the worst within and across cases (NG and UK).

Bldg101 BEU is an outlier, however, Bldg101 performance is considered peculiar. It could help reveal other potential factors (other than weather, HVAC, and base loads) that could cause higher BEU in the Nigeria cases, hence further investigated. Nonetheless, the examination so far established that bldg101 relied largely on: fossil-fuel, two large generators and estimated billing for the period under review, and these are plausible causes.

The result correlates earlier analysed results based on PMs and KPIs, confirming it as a poor performing building. It recorded an average NPI was 246% higher than the CIBSE benchmark value (Table 6:11). However, a further instigation is required for its confirmation; and to segregate its weather-related and non-weather-related BEU in achieving clear delineation.

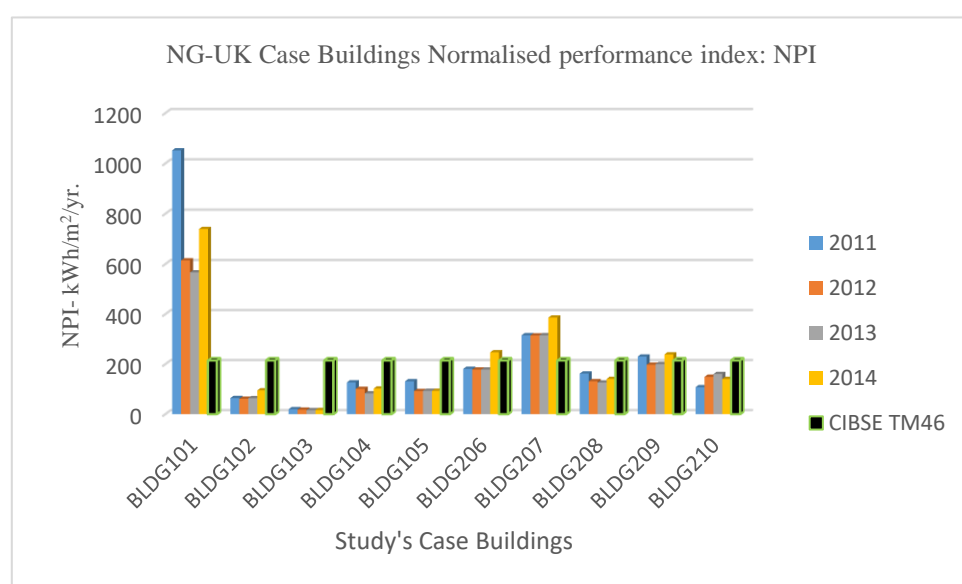


Figure 6.8: NG-UK Case Buildings' NPI Benchmarked against CIBSE TM46

Table 6:11: NG-UK Case Buildings' Average NPI

NG-UK CASE BUILDINGS' Average NPI										
Year: 2011-2014	Bldg101	Bldg102	Bldg103	Bldg104	Bldg105	Bldg206	Bldg207	Bldg208	Bldg209	Bldg210
Average NPI	743	71	17	103	102	196	333	140	216	139
CIBSE TM46	215	215	215	215	215	215	215	215	215	215
% Variance against CIBSE	246	-67	-92	-52	-52	-9	55	-35	1	-35

Within the Nigeria cases, bldg102, bldg103, bldg104 and bldg105 performed well against the benchmark value with lower NPI values between -52% and -92% variances. Nevertheless, based on only-office-use category, bldg104 and bldg105 are at the same degree of execution; and executed better than bldg101.

Bldg102 (office-religion-use), and 103 (office-domestic-use), are the best performing buildings. However, it is noticed bldg103 ( $208.0\% < \text{benchmark}$ ) is an outlier like bldg101 ( $245.6\% > \text{benchmark}$ ) to the benchmark. Plausible explanation could be that, the CIBSE TM46 typical office benchmark is for homogenous office cases; whereas, bldg103 is likely a mix-fit benchmark in current heterogeneous cases.

Amongst the UK cases, bldg207 performed poorly against the benchmark value with the largest differences. Bldg207 had an average NPI of  $333\text{kWh/m}^2/\text{year}$ , indicating about 55% higher than benchmark value. Based on average NPI and CIBSE TM46 benchmark, it is the poorest performing building amongst UK and NG buildings after bldg101.

Bldg209 slightly performed below reference benchmark with an average NPI of  $216\text{kWh/m}^2/\text{year}$ . This is about 0.5% more than the typical value, thus the performance can be adjudged the same with reference building. Although, its performance for 2011 and 2014 are slightly above the benchmark, nonetheless the overall result indicates good performance.

It is profound to note that bldg206 performed better than bldg207 and bldg209 base on NPI and CIBSE TM46 benchmark. When compared with benchmark value, its average NPI of  $196\text{kWh/m}^2/\text{year}$ , was 8.8% lower. This confirms earlier findings based on BEUI where it also performed better than bldg207 & bldg209.

Bldg208 and bldg210 performed better than the benchmark standard (Table 6:11 and Figure 6.8). Their average NPI values of  $140\text{kWh/m}^2/\text{year}$  (bldg208) and  $139\text{kWh/m}^2/\text{year}$  (bldg210), are  $35\% <$  than benchmark value. It could be reasoned that bldg210 is the best overall EE performing building within the UK cases.

## 6.8 ENERGY PERFORMANCE LINES

This section investigates the effect of climate on BEP based on the likely impact of degree-days variability on case buildings' BEU variability. Current study employs, the ordinary least squares (OLS) regression method based on the line of best fit as case buildings' EPL. Case study buildings' EEP assessment and benchmark is therefore based on study equation 10 (section 4.7.3).

The average of 2653CDD is used in Lagos (Sivak, 2009) sampled cases, while average of 2176HDD is used for Chelmsford (VESMA, 2016) sampled cases for the calculation. Current study calculated the average daily temperature and the amount of degree by which the base temperature is exceeded to determine the degree days for cooling and heating (Layberry, 2009; Ogunsole and Prucnal-Ogunsole, 2010).

Temperature set-point of 20°C for Lagos (Ogunsole and Prucnal-Ogunsole, 2010), and 15.5°C for Chelmsford (VESMA, 2016), were used as different bases for DD calculations for the two locations. However, a past study used 26.4°C (Batagorawa, Hamza and Dudek, 2011) for Lagos, but current study used 20°C instead, as it is closer to real life context. The base temperature indicates the temperature below or above which a building must be heated or cooled. It is also an index of the building energy demand for cooling or heating. The CDD and HDD are calculated by subtracting 15.5 (HDDs) or 20.0 (CDDs) from the average daily temperature, and adding up all the positives over monthly and up to yearly period (Sivak, 2009).

The preposition that BEU is directly proportional to the variations in temperature is hereby tested. The linear correlation coefficient ( $r$ ), between temperature change and BEU is examined. Also, the used of the OLS regression model helped in disaggregating BEU into weather-related (HVAC) and non-weather-related (base loads: coefficient of constant). Additionally, the coefficient of determination ( $r^2$ ), which gives the measure of variation of BEU (the dependent variable) that directly related to the variation of DDs (independent variable) is considered with null hypothesis as follows:

- $H_0$ : weather condition variability is not significantly related to BEU; hence, not a predictor of BEP in Nigeria and UK.

### 6.8.1 NG-UK Case Buildings

An overview of the association between study's case buildings' BEU; and CDDs & HDDs variability are presented using line plots (Figure 6.9, Figure 6.10 and Figure 6.11). The CDD and HDD variability line plots indicated the performance of BEU against change in external temperature. Also, bldg101 is removed from the line plot (Figure 6.10) to expose the actual trend of other Nigeria case buildings.

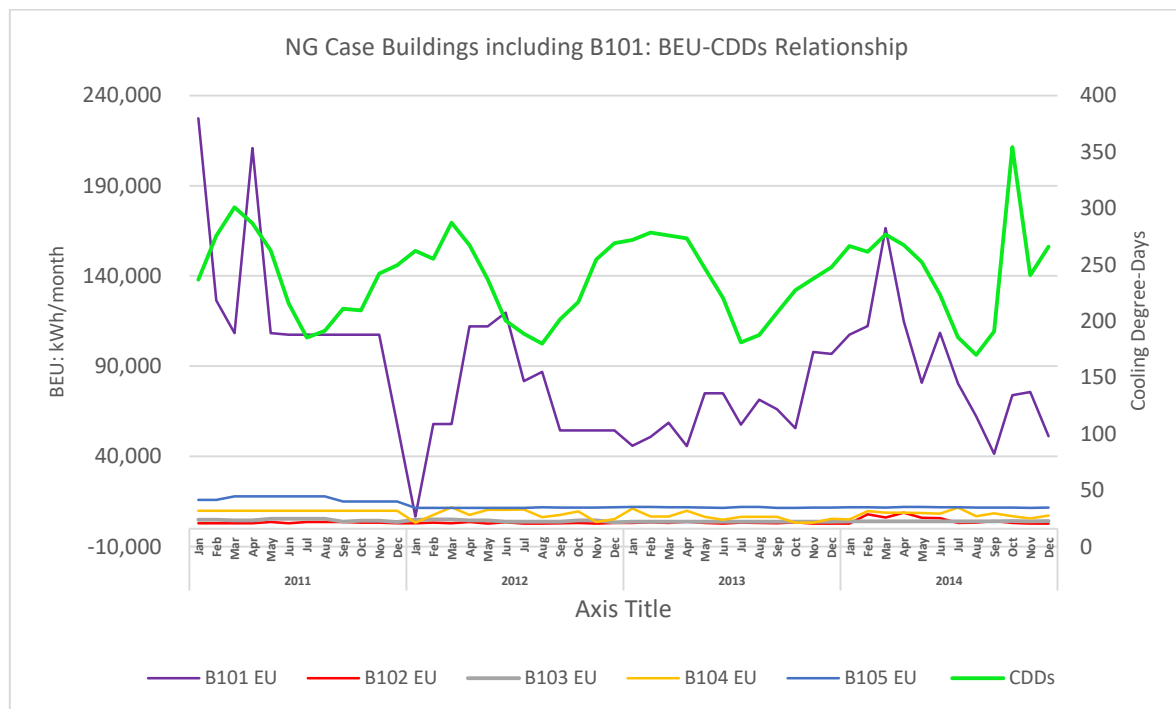


Figure 6.9: NG Case Buildings: BEU-CDDs Relationship

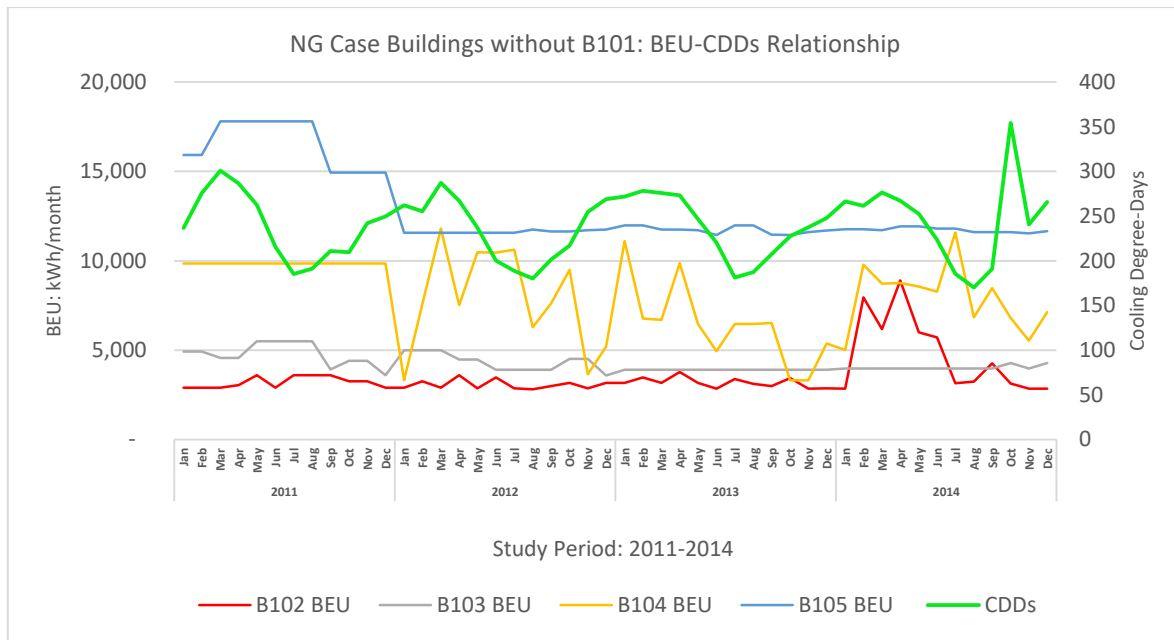


Figure 6.10: NG Case Buildings without B101: BEU-CDDs Relationship

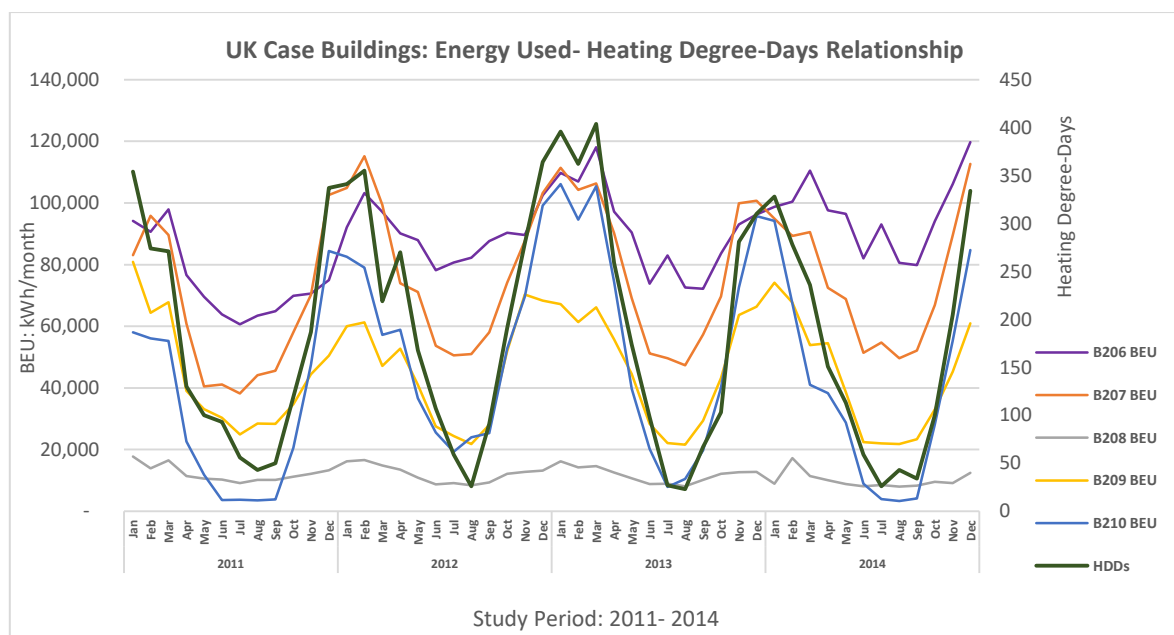


Figure 6.11: UK Case Buildings: BEU-CDDs Relationship

The line plot BEU analysis could not indicate how variation in external temperature (DDs) affects variation in case buildings' BEU. Also, the need for a predictive model (weather-related), as a benchmark, becomes necessary, as it aids the design, construction and operation of buildings. This informed the use of OLS regression method with results for the ten case buildings presented in Table 6.12.

Table 6:12: NG-UK Case Buildings EPL- OLS Linear Regression Results

NG-UK Energy Performance Line (EPL) Regression Table										
OLS Results	Bldg101	Bldg102	Bldg103	Bldg104	Bldg105	Bldg206	Bldg207	Bldg208	Bldg209	Bldg210
N	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00
$\mu$ EU: kWh/m <sup>2</sup> /month	87675	3556	4264	8020	12901	88223	74216	11537	45172	44718
$\mu$ Monthly CDDs/HDDs	239	239	239	239	239	185	185	185	185	185
Pearson Correlation	0.08	0.12	0.07	-0.04	0.01	0.71	0.94	0.82	0.94	0.96
$\alpha$ p-value level of sig.	0.29	0.22	0.32	0.39	0.48	0.00	0.00	0.00	0.00	0.00
Model Summary										
R	0.08	0.12	0.07	0.04	0.01	0.71	0.94	0.82	0.94	0.96
R Square	0.01	0.14	0.01	0.00	0.00	0.50	0.88	0.67	0.88	0.92
Adjusted R Square	-0.02	-0.01	-0.02	-0.02	-0.02	0.49	0.87	0.66	0.98	0.91
df	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00
F change	0.30	0.63	0.23	0.08	0.00	46.38	323.81	91.34	328.62	501.73
sig. F change	0.59	0.43	0.64	0.78	0.96	0.00	0.00	0.00	0.00	0.00
Coefficients										
Unstandardised. Coeff: Constant	67522	2640	4036	8614	12791	72596	41061	8100	19771	-2541
Ditto: Slope DDs: 2011-2014	84.30	3.83	0.95	-2.49	0.46	84.33	178.92	18.54	137.07	255.04
T-test for constant	1.81	2.26	8.32	4.05	6.24	26.56	18.71	18.92	11.85	-1.01
Sig. for constant	0.76	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
T-test for slope	0.55	0.79	0.48	-0.28	0.05	6.81	18.00	9.56	18.13	22.40
Sig. for slope	0.59	0.43	0.64	0.78	0.96	0.00	0.00	0.00	0.00	0.00
Stand. Coefficient $\beta$	0.08	0.12	0.07	-0.04	0.01	0.71	0.94	0.82	0.94	0.96
Confidence interval	0.95	0.95	0.95	0.95	95.00	95.00	95.00	95.00	95.00	95.00

### I. The Nigeria Case Buildings

Bldg101 linear regression result (Table 6:12) and the EPL (Figure 6.12), reveals difference between its BEU fluctuation ( $\sim 87,674.83$  kWh/monthly  $\mu$ ), and CDDs variability ( $\sim 239.06$  monthly  $\mu$ ). Likewise, the result shows a weak positive correlation between bldg101 BEU and CDDs at  $\beta = 0.081$ ,  $p = 0.586$  and  $R^2 = 0.006$ . The non-significant correlation shows that weather have minimal impact on its BEU.

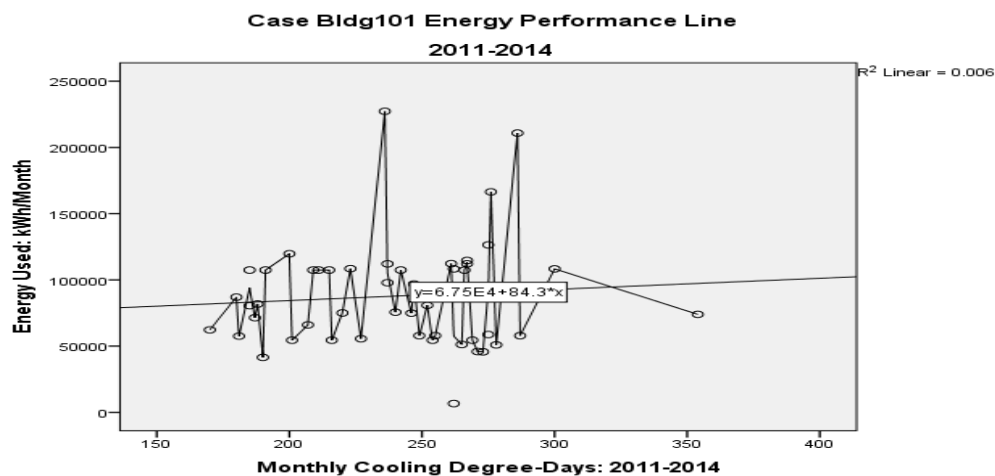


Figure 6.12: Bldg101 EPL based on OLS linear Regression



Based on the OLS model, weather (CDDs) accounts for 23% of the monthly mean ( $\mu$ ) of bldg101 BEU. While the intercept (base loads), accounts for 77% (67,522.04 kWh/month). Also, an extra day increase in CDD will lead to its BEU increase by 84.299 kWh/month. However, its F-test statistics regression result:  $F(1, 46) = 0.301$ ,  $p\text{-value} = 0.586$ , also fulfils condition of null hypothesis that the overall model coefficient is equal zero. This confirms that variation in CDD is not a significant predictor of bldg101 BEU.

Bldg101 coefficient of determination ( $R^2 = 0.01$ ), also confirmed that about 1% of the variation in CDDs is explained by the variation in bldg101 BEU. The remaining 99% of weather variation is unexplained by its BEU fluctuation. It could be that bldg101 base load BEU is too high; and could possibly explained for by other contextual factors as identified in study.

Result for Bldg102, 103,104 and 105 BEP were also analysed and discussed via the same protocol used for bldg101. It indicates 1.0% of the variation in CDD is explained by variation in their BEU, the balance 99.0% cannot be explained.

Bldg102 BEU (Table 6:12 and Figure 6.13), is not largely influence by weather variability, but rather other underlying factors as identified earlier. However, it has the best performance amongst the Nigeria cases.

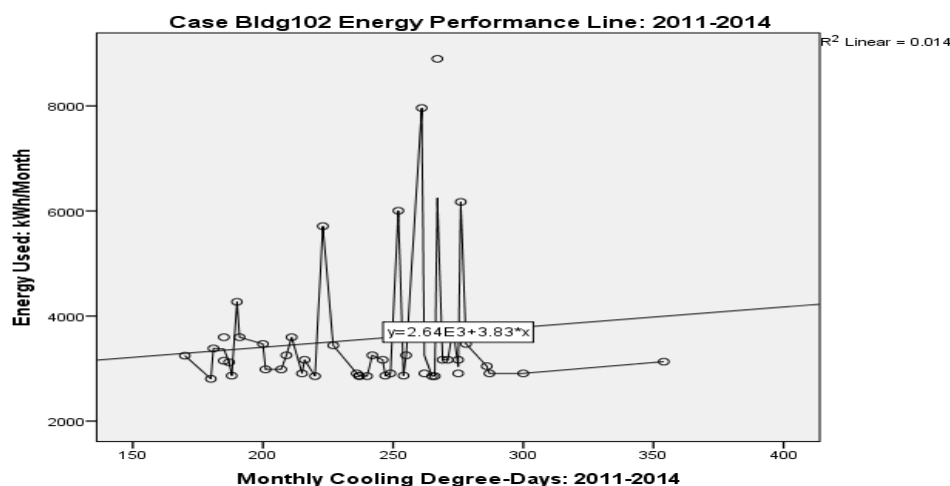


Figure 6.13: Bldg102 EPL based on OLS linear Regression

Bldg103 result (Table 6:12 and Figure 6.14), also signify weak positive correlation between its BEU and CDDs variability. Its regression analysis resulted in  $\beta = 0.070$ ,  $p = 0.637$  and  $R^2 = 0.005$ , signifying weak positive correlation.

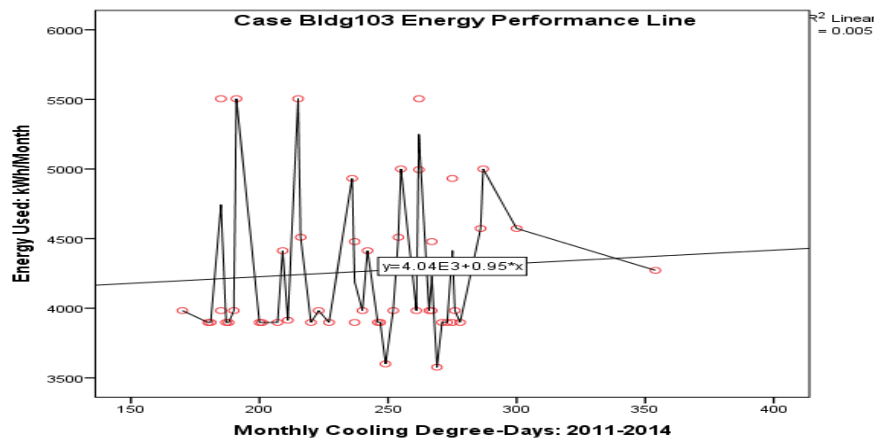


Figure 6.14: Bldg103 EPL based on OLS linear Regression

The EPL of bldg104 (Table 6:12 and Figure 6.15), exhibits weak negative affiliation between its BEU and CDDs variations. Its base load (8,614.31 kWh) exceeded its  $\mu$  monthly BEU (8019.97 kWh) resulting in negative gradient (-2.49 kWh). It could suggest the existence of frequent power outages, which often result in non-use of air conditioners due to reliance on generators.

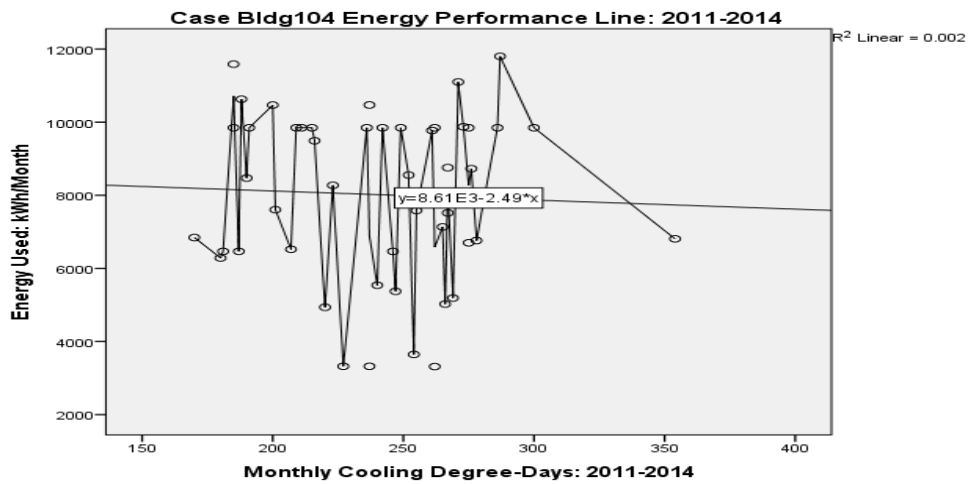


Figure 6.15: Bldg104 EPL based on OLS linear Regression

Bldgs105 BEP result (Table 6:12 and Figure 6.16), likewise reveals weak positive correlation. The equation of the line of this building EPL suggest that its base load is about 99.2% (12,791.13 kWh/month), while only 0.8% (110.0 kWh/month) is used for cooling. However, its slope suggests that 0.46 kWh of energy are used for every extra degree-day.

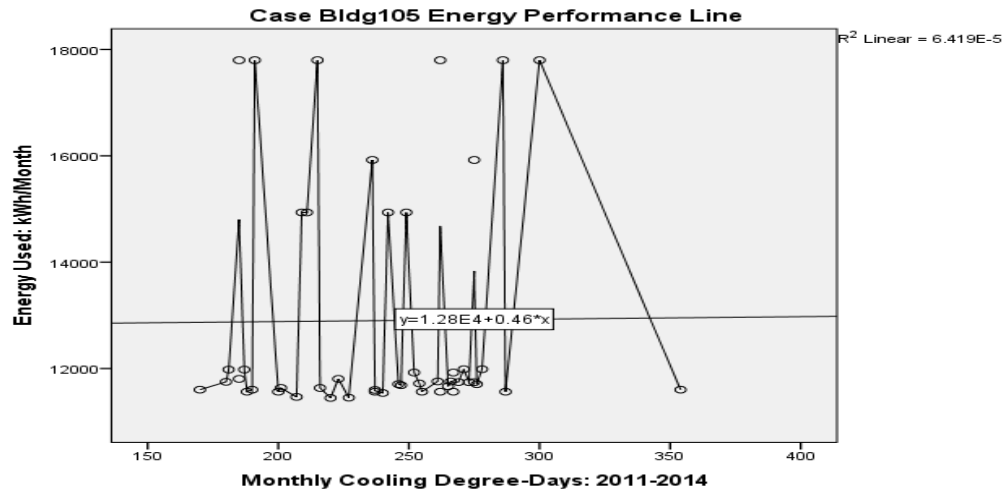


Figure 6.16: Bldg105 EPL based on OLS linear Regression

## II. The UK case buildings

Bldg206 EPL regression model result (Table 6:12 and Figure 6.17), reveals a strong positive linear correlation between its BEU fluctuation and HDDs variability. It suggests a coefficient of determination of 50%, which implies that 50% of fluctuation in its BEU can be explained by variations in weather condition.

The line of best fit suggests a base load of 72596.40 kWh/month, and the gradient indicates 84.33 kWh of BEU for every additional Degree-day. It also, reveals that weather-related BEU (HVAC) is about 17.7% of its monthly  $\mu$  UE of 88,223.48 kWh. Whilst, 82.3% (base loads BEU) is non-weather-related. However, it satisfied both the conditions of T-test and the F-test:  $F(1, 46) = 46.38$ ,  $p\text{-value} = 0.000$ , for alternative hypothesis that the overall model coefficient is not equal zero. Also, it confirms that variation in heating degree-day is a significant predictor of bldg206 BEU.

Analysis and discussion of results for Bldg207, 208, 209 and 210 BEP were also based on the same procedure used for bldg206. Across the UK buildings at least 50% of the variation in CDD is explained by variation in their BEU. Their results also reveal strong correlation between BEU fluctuation and HDDs variability.

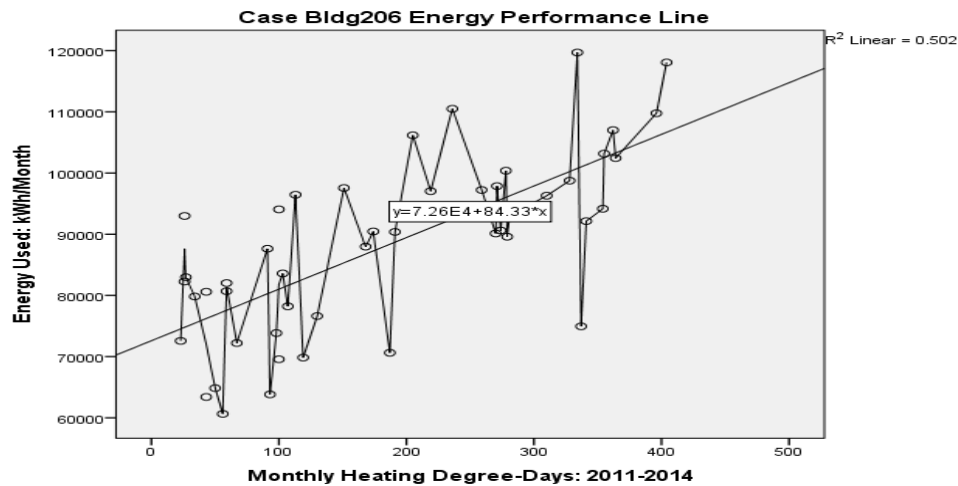


Figure 6.17: Bldg206 EPL based on OLS linear Regression

The result for Bldg207 (Table 6:12 and Figure 6.18), shows that its line of best fit represents a positive perfect linear correlation. The based load is 55.3% of its monthly  $\mu$  of BEU, whilst the weather-related load is 44.7% (33,155.60 kWh/month). It could be deduced that bldg207 ( $R^2 = 0.879$ ) energy performer is better than bldg206 ( $R^2 = 0.502$ ) due to its higher coefficient of determination. About 87.9% variation in its BEU can be explained by changes in HDDs. However, bldg207 is more vulnerable to variation in weather conditions than bldg206 as reflected in the higher gradient.

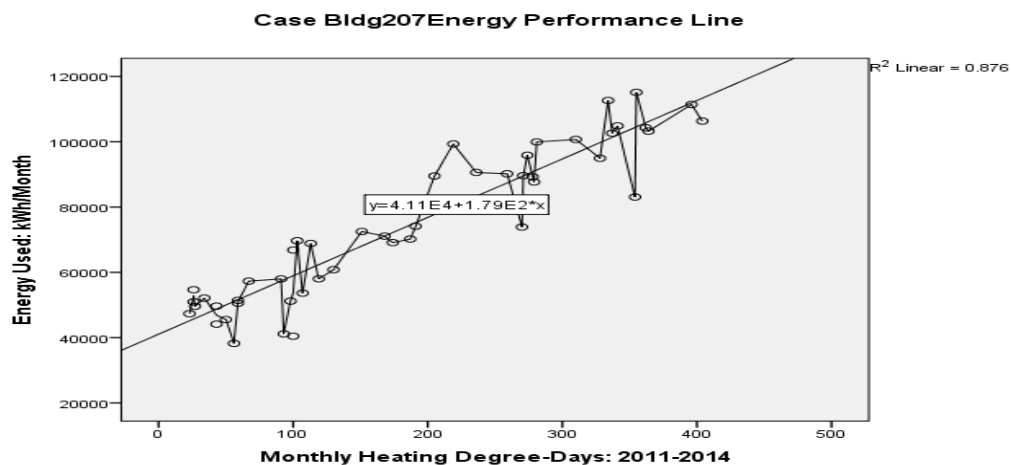


Figure 6.18: Bldg207 EPL based on OLS linear Regression

Bldg208 line of best fit (Table 6:12 and Figure 6.19), also indicates a slightly better performer than Bldg206 and lower performer than bldg207. Its base load of 8100.2 kWh/month (70.2% of the monthly  $\mu$ ), reflects 29.8% load balance for HVAC related-BEU. It also indicates that

about 66.6% (coefficient of determination) of fluctuation in its BEU can be explained by variations in weather condition.

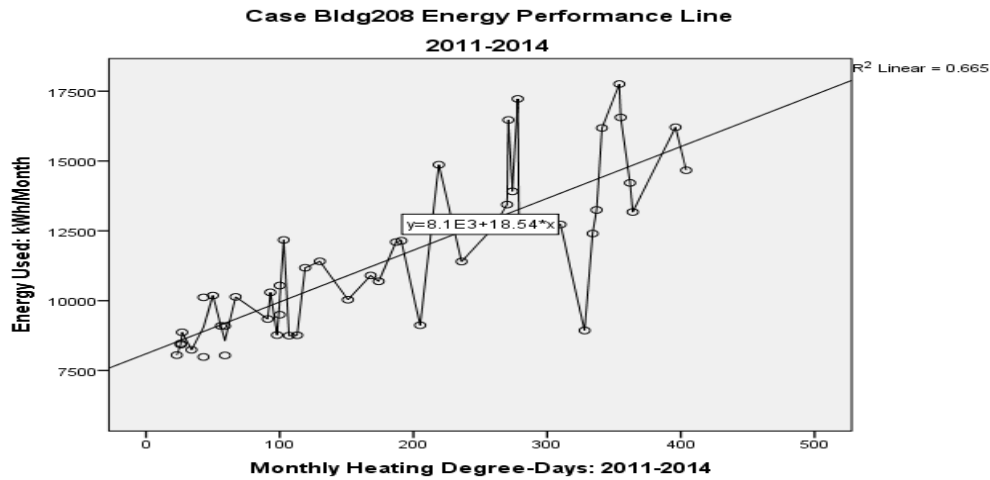


Figure 6.19: Bldg208 EPL based on OLS linear Regression

Case bldg209 line of best fit (Table 6:12 and Figure 6.20) indicates similar performer with bldg207. The base load is 43.8% of its monthly average, and weather-related HVAC is 56.2%. The indicated slope also suggests a 137.07 kWh of BEU for every day increase in HDDs. also, confirms that variation in HDD is a significant predictor of its EEP. Hence, its energy performance is seen to be better than bld206 & 208 but at parity with bldg207.

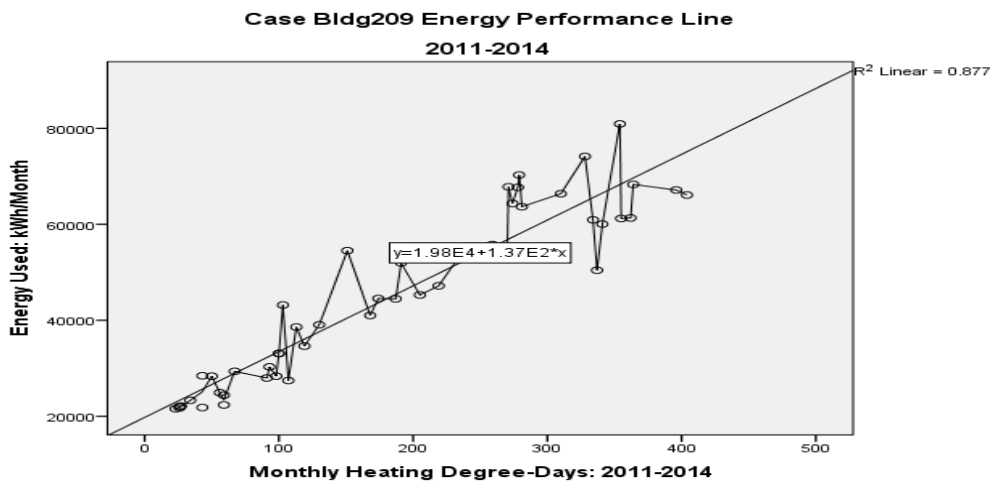


Figure 6.20: Bldg209 EPL based on OLS linear Regression

Bldg210 indicated the best performing building within cases base on its line of best fit (Table 6:12 and Figure 6.21). The line of best fit indicates a negative base load (-2,543.64 kWh/month)

for non-weather-related BEU. It signifies sometimes, the monthly  $\mu$  HVAC loads could be up to 47,262 kWh of energy. This is about 5.7% increases over its monthly  $\mu$  of BEU (44,718.08 kWh). This is confirmed by its  $R^2 = 0.916$ , depicting that about 92.0% of variability in its BEU is accounted for by fluctuations in HDDs.

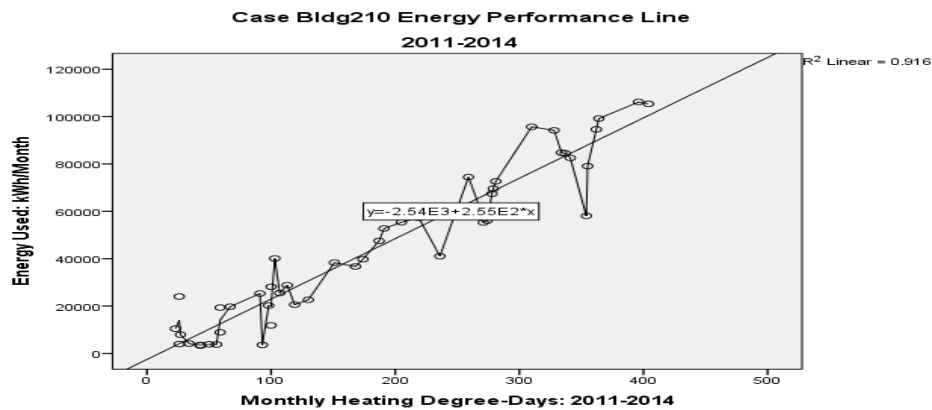


Figure 6.21: Bldg210 EPL based on OLS linear Regression

Findings indicate that all Nigeria case buildings model satisfied the null hypothesis test that overall model coefficient is equal zero. Their results showed that overall F-test values are not significant with p-values  $> 0.05$ , hence, regression models established poor performance lines in these buildings as indicated under:

- Bldg101 BEU and CDDs at T-test ( $\beta$ ) = 0.081,  $t(46) = 1.814$ ,  $p = 0.586 > 0.050$ , and  $R^2 = 0.006$ ; while it's  $F(1, 46) = 0.301$ ,  $p = 0.586 > 0.50$ .
- Bldg102 T-test recorded  $\beta = 0.116$ ,  $t(46) = 2.259$ ,  $p = 0.431 > 0.050$ , and  $R^2 = 0.014$ ; while it's F-test result ( $F = 0.630$ ;  $p = 0.431 > 0.05$ ).
- Bldg103 T-test resulted in  $\beta = 0.070$ ,  $t(46) = 8.315$ ,  $p = 0.637 > 0.050$ , and  $R^2 = 0.005$ ; its F-test result ( $F = 0.226$ ;  $p = 0.637 > 0.05$ ).
- Bldg104 T-test ( $\beta$ ) = -0.042,  $t(46) = 4.047$ ,  $p = 0.779 > 0.050$ , and  $R^2 = 0.002$ ; while it's F-test result ( $F = 0.080$ ;  $p = 0.779 > 0.05$ ); and
- Bldgs105 reveals  $\beta = 0.008$ ,  $t(46) = 6.240$ ,  $p = 0.957 > 0.050$ , and  $R^2 = 0.000$ ; while it's F-test result ( $F = 0.003$ ;  $p = 0.957 > 0.05$ ).

Since the F-test and T-test statistics including respective critical  $\alpha$  indicated non-significant tests for the model result, consequently, the prediction formula based on OLS regression

methods is inadequate for the NG case buildings. Whereas, the prediction formula for the UK case buildings for the F-test satisfies the alternative hypothesis that the overall model coefficient is not equal zero. Besides, it confirms that variation in heating degree-day is a significant predictor as shown under:

- Bldg206 T-test ( $\beta$ ) = 0.709,  $t(46) = 6.81$ ,  $p = 0.000$ , and  $R^2 = 0.50$ ; while it's  $F(1, 46) = 323.81$ ,  $p = 0.000$ .
- Bldg207 its BEU variability and HDDs changes are strongly affiliated at  $\beta = 0.936$ ,  $t(46) = 17.99$ ,  $p = 0.000$ , and  $R^2 = 0.876$ ;  $F = 323.805$ ,  $p = 0.000$ .
- Bldg208 result  $\beta = 0.816$ ,  $t(46) = 9.56$ ,  $p = 0.000$ , and  $R^2 = 0.665$ ;  $F$ -statistics = 91.338,  $p = 0.000$ .
- Bldg209 line of best fit indicates  $\beta = 0.937$ ,  $t(46) = 18.13$ ,  $p = 0.000$ , and  $R^2 = 0.877$ ;  $F$ -test = 328.624,  $p = 0.000$ .
- Bldg210 is T-test ( $\beta = 0.957$ ,  $t(46) = 22.40$ ,  $p = .00$ , and  $R^2 = 0.916$ );  $F$ -test = 501.728,  $p = 0.000$ .

## 6.8.2 NG-UK Case Comparison based on EPL

This section compares study buildings within and across cases (Nigeria and UK), using the Degree-Days predictive model based on OLS regression method. Table 6:13 and Table 6:14 presents summary of each building's un-standardised and standardised predictive models,  $R$ -values, and  $R^2$ -values within cases. Nigeria and the UK case buildings are compared using the study null hypothesis.

Table 6:13: NG Case Buildings EPL Predictive Models

NG CASE BUILDINGS' ENERGY PERFORMANCE LINE PREDICTIVE MODEL TABLE BASED ON OLS REGRESSION					
Energy Estimation Model:	BLDG101	BLDG102	BLDG103	BLDG104	BLDG105
Unstandardized	$\hat{Y} = 76522.04 + 84.30 * X$	$\hat{Y} = 2639.71 + 3.83 * X$	$\hat{Y} = 4036.00 + 0.95 * X$	$\hat{Y} = 8624.31 - 2.49 * X$	$\hat{Y} = 12792.40 + 84.33 * X$
Standardised	$\hat{Y} = \beta(X) = 0.081 * X$	$\hat{Y} = \beta(X) = 0.116 * X$	$\hat{Y} = \beta(X) = 0.070 * X$	$\hat{Y} = \beta(X) = -0.042 * X$	$\hat{Y} = \beta(X) = 0.008 * X$
Corr Coeff. ( $r$ )	0.081	0.116	0.070	0.042	0.008
Coeff deter. ( $r^2$ )	0.007	0.013	0.005	0.002	0.000
% Explained	0.7	1.3	0.5	0.2	0.0
% Unexplained	99.3	98.7	99.5	99.8	100.0

Table 6:14: UK Case Buildings EPL Predictive Models

UK CASE BUILDINGS' ENERGY PERFORMANCE LINE PREDICTIVE MODEL TABLE BASED ON OLS REGRESSION					
Energy Estimation Model	BLDG206	BLDG207	BLDG208	BLDG209	BLDG210
Unstandardized	$\hat{Y} = 72596.40 + 84.33 * X$	$\hat{Y} = 41060.57 + 178.92 * X$	$\hat{Y} = 8100.29 + 18.92 * X$	$\hat{Y} = 19770.78 + 137.07 * X$	$\hat{Y} = -2534.46 + 255.04 * X$
Standardised	$\hat{Y} = \beta (X) = 0.09X$	$\hat{Y} = \beta (X) = 0.936X$	$\hat{Y} = \beta (X) = 0.816X$	$\hat{Y} = \beta (X) = -0.937X$	$\hat{Y} = \beta (X) = 0.957X$
Corr. Coeff (r)	0.710	0.936	0.816	0.937	0.957
Coeff. deter (r <sup>2</sup> )	0.504	0.876	0.666	0.878	0.916
% Explained	50.4	87.6	66.6	87.8	91.6
% Unexplained	49.6	12.4	33.4	12.2	8.4

Previous results revealed weather condition variability based comparison indicates that EPL of the Nigeria cases performed very poor compared to the UK cases. The analyses point to the Nigeria case buildings all satisfying the condition of null hypothesis that regression model coefficient is not equal zero. Their R<sup>2</sup>-values ranges between 0.00 and 0.013 explaining only between 0.0% and 1.3% of variations in weather condition by changes in their BEU. These buildings regression statistics confirms that weather condition variability is not significantly related to their BEU; hence, not a predictor of their BEP.

The UK case buildings satisfied the conditions of study alternative hypothesis that model coefficient is equal zero. Their R<sup>2</sup>-values ranges between 0.502 and 0.916 explaining between 50.2% and 91.6% of variations in weather condition by changes in their BEU. All cases confirmed that weather condition variability is significantly related to their BEU; hence, a predictor of their BEP. UK buildings' predictive models can explain more than at least more 50.0% of weather variations from fluctuation in their BEU. Whilst, Predictive models for the Nigeria case building cannot explain at least 93.0% of fluctuation in weather conditions base on variations in their BEU.

Cases were ranked based on the standardised  $\beta$  predictive models and its predictive power (Table 6:13 and Table 6:14). All UK's cases produced very strong predictive model with: Bldg210 ( $\hat{Y} = \beta (X): 0.957X$ ) ranked 1<sup>st</sup>; Bldg207 ( $\hat{Y} = \beta (X): 0.936X$ ) and Bldg209 ( $\hat{Y} = \beta (X): -0.937X$ ), ranked second best jointly in performance across cases. While Bldg208 ( $\hat{Y} = \beta (X): 0.816X$ ) and Bldg206 ( $\hat{Y} = \beta (X): 0.709X$ ) ranked as 4<sup>th</sup> and 5<sup>th</sup> respectively in declining predictive power and performance.



The Nigeria case buildings ranked very poor in performance having weak non-significant predictive model. They ranked as thus: Bldg102 ( $\hat{Y} = \beta(X): 0.116 * X$ ) ranking 6<sup>th</sup>; Bldg101 ( $\hat{Y} = \beta(X): 0.081 * X$ ) ranked 7<sup>th</sup>; and Bldg103 ( $\hat{Y} = \beta(X): 0.070 * X$ ) ranked 8<sup>th</sup>. While Bldg104 ( $\hat{Y} = \beta(X): -0.042 * X$ ) ranked 9<sup>th</sup>; and Bldg105 ( $\hat{Y} = \beta(X): 0.008 * X$ ) ranked 10<sup>th</sup> across the ten cases. The EPL for the Nigeria cases is still the best basis for assessing and benchmarking their performance against UK cases for current heterogeneous study. Thus, all UK case buildings are more energy efficient than the Nigeria cases.

## 6.9 SUMMARY

The chapter examined the BEP of study's buildings within and across cases based on their environmental, social and economic performance. The aim is to understand the critical factors affecting case buildings' energy performance.

Analysis of case building BEU based on Study PMs and KPIs (via respective equations), reveals Bldg101 as an outlier with the highest energy consumption amongst NG cases. Also, differences are discovered in the type of fossil-based electricity used in the two countries. The NG case buildings have about 84.2% (average) dependence on fossil-fuel-based electricity source. Whereas, the UK cases have about 38.2% average dependence on fossil-fuel electricity, for the accounting period.

High frequency of power outages in Nigeria, and economic consideration in the UK accounts for the differential in energy source across cases. This is evidence as NG cases use diesel and PMS based on-site generation of electricity via generators. It is associated with sporadic invoicing as indicated in the BEU trend lines. Whilst, the UK buildings use natural gas off-site (vendor supplied) electricity. It is evidence in the BEC analysis as cost of gas electricity is cheaper than grid electricity. These factors strongly impact case buildings' BEUI, BCO<sub>2</sub>I and BECI when benchmarked within and across cases.

Another factor discovered to have influenced case BEP is the type of billing methods (metered and estimation), employed in the two countries. Whereas, the UK case buildings have installed DAS meters that captured real-time BEU with accurate real-time BEU data. The Nigeria buildings have digital (Pay-as-use) meters installed, with meter readings that are rarely used.

Instead, buildings are invoice based on estimation billing mode by service provider (Nigeria Power Holding Company). However, when the invoiced charge is disaggregated based on unit of electricity tariff, it translated in increased pseudo BECI and BCO<sub>2</sub>I for case buildings.

The energy used line-plot (time-series analysis), is used in examination of consumption patterns. All cases but bldg101 exhibits a defined but non-cyclical and non-seasonal pattern of consumption for the NG case buildings. Contrariwise, the UK buildings indicated defined cyclical and season trend, with majority having slightly downward trend of BEU over study time.

NPI benchmarking of case buildings against CIBSE TM46 further indicates that Bldg101energy performance was found to be extremely poor. Also, within the Nigeria cases, bldg102, 103, 104 & 105 performed better than the benchmark value. While the UK cases, bldg207 performance is the poorest against benchmark value. However, Bldg206 was found to have performed better than bldg207 and bldg209; whilst, bldg208 and bldg210 performed better than the benchmark

The EPL (via OLS regression method) is applied as the final assessment and comparison of case buildings' EEP based on weather conditions variability. It was discovered that weather variability is not a critical factor to the Nigeria cases, whereas, it was critical to the UK buildings. Also, the line of best fit for case buildings indicate that a better EEP for the UK building than NG cases. All the UK case buildings have very strong OLS predictive models whilst, the Nigeria case buildings have very weak OLS predictive models.

Finally, the identified contextual factors: fuel sources and types, on-site power generation (use of generators), high frequency of power outages, billing methods (metered and estimation billing), and over invoicing (due to poor supply chain management), were some of the issues identified with cases especially the NG case buildings. It becomes imperative to further examine these silent underlying factors to ascertain the critical factors affecting BEP in Nigeria compare to the UK. The identified factors are social-economic issues (behavioural, operations and maintenance), hence, the need for a survey tool.

## 7 Chapter Seven: Factors that Affect Building Performance

### 7.1 INTRODUCTION

This section examined the critical factors that affected BEU and its EEP across the study buildings. The chapter objective is to present the analysis of data gathered through the three survey tools used in answering the research questions. The section focuses on the perceptions of case building users, owners, operators and professional FMs. It is divided into two-phases: phase one obtained users, owners and FM practitioners' opinions through quest-surv1 and quest-surv2; whilst phase two obtained perceptions of owners and operators through interviews (interv-surv4), and validation of findings via quest-surv3 from all respondents within and outside case buildings.

Quest-surv1 data analysis was based on the individual case, whilst quest-surv2, interv-surv4 and quest-surv3 data were analysed generally. However, overall chapter objective is to investigate the following:

- Barriers and drivers to BEU and BEP in Nigeria compare to the UK
- Appropriate operational/ technical, managerial, behavioural and low carbon solutions for BEP available in Nigeria and the UK
- Impacts of SP and FM on organisation corporate policy and BEP
- Selection and evaluation appropriateness of energy PMs and KPIs as tools for BEP
- Policy and behavioural approaches in the west, and
- SSP and SFM as drivers for achieving low carbon goal in existing buildings.

### 7.2 USERS' PERSPECTIVE BASED ON QUEST-SURV1: 1<sup>ST</sup> POE

#### 7.2.1 Demographics

Quest-surv1 study respondents (N = 166; valid n = 163) were categorised into country location, case building investigated, the user's status and knowledge of case buildings (Table 7:1). All the participants worked in case buildings located in Lagos (n= 85), Nigeria and Chelmsford (n= 78), UK. However, the largest respondents were obtained from bldg101 (58.1%), whilst the least responses came from bldg208 (1.3%) (Figure 7.1).

Table 7.1: Quest-Surv1 Demographics

Quest-Surv1 Demographics	
location:	Response Percent
Nigeria	52.10%
United Kingdom	47.90%
Case Buildings:	Response
BLDG101	58.10%
BLDG102	16.30%
BLDG103	5.80%
BLDG104	12.80%
BLDG105	7.00%
BLDG206	34.20%
BLDG207	19.70%
BLDG209	21.10%
BLDG208	1.30%
BLDG210	23.70%
Participants	Response
Staff	64.80%
Students	21.20%
Employees of business organisation	9.10%
Employers / Owners	4.80%
Participants' Experiences with Case buildings	Response
< 5years	55.10%
6-10years	22.20%
11-15years	4.40%
16-20years	1.90%
21-25years	3.80%
Other	12.70%
Days spend inside building per working week	Response
1day	3.10%
2days	6.80%
3days	16.10%
4days	11.20%
5days	60.90%
Other	1.90%
Average hour(s) per day in building per working day	Response
1-2hrs	2.50%
3-4hrs	9.40%
4-5hrs	7.50%
6-8hrs	75.60%
Other	5.00%

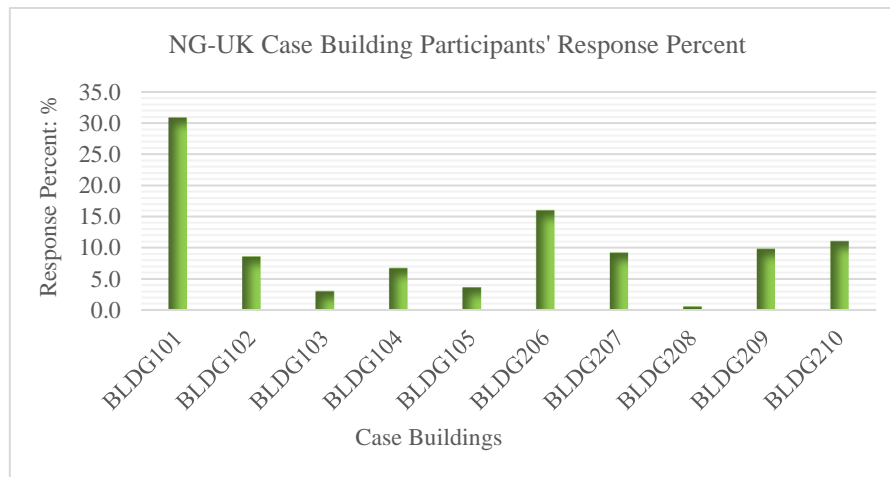


Figure 7.1: NG-UK Case Building Participants' Response Percent

Most users of case buildings were staff (64.8%) and students (21.2%). The employees of business organisations (9.10%) and employers/ owners (4.8%) have lowest participations. However, employee and staff are synonyms and did confuse the respondents, due to error in

survey design. Hence, both categories were combined as staff, consequently, aggregate staff response (n = 122), became the largest representation in response (73.9%).

Majority of the respondents (about 55.1%) in both countries have  $\leq 5$  years experience with respective case buildings. Those with between 6-10 years' experience came next with about 22.2%. The users with 16-20 years' experience have the least response (1.9%). The analysis reveals most respondents have good working knowledge of case buildings.

The data indicate the same working day pattern both for Nigeria and the UK. Also, most occupants use these buildings at least 5 days per week. Respondents' working-day reveals that most users (60.9%; n = 98) spend 5 days in case buildings, and 1.9% of users (n = 3) spend > 6 days. Whilst, building occupancy-hour result reveals that the majority (75.6%) of respondents spend 6-8 hours per day in case buildings. The results point to the same normal office working hour and pattern for both countries.

Study Cronbach's alpha test result for variables indicated:  $\alpha = 0.924$  and  $0.934$  on standardized items, with N= 62, at an acceptable strong reliability level of 0.70 alpha value (Bacon, 2004).

### 7.2.2 Installed Technology Perceived Benefits

Participants (N=166), rates the relevance of installed technologies in buildings; and perception of technologies as drivers for BEP based on 5-point Likert's scale. The result for these technologies: Building Energy Management System (BEMS) / Building Automaton System (BAS); Data Acquisition System (DAS); access control lock (ACL); lighting control-Sensors (LC-Sensors); and temperature & humidity controls (THC) presented as follows:

#### *I. Identification and Perceived Benefits of Installed Technologies*

Generally, more > 50% of the respondents (NG and UK), agreed that: ACL (about 66.0%; valid n = 154); LC-Sensor (67.8%; n = 151); and HMC (54.7%; n = 151), are very relevant. While, about 50% agreed that DAS (44.4%; n = 148) and BEMS (41.0%; n = 148), are very useful. Hence, they are perceived useful in managing BEP in Nigeria and the UK (Figure 7.2).

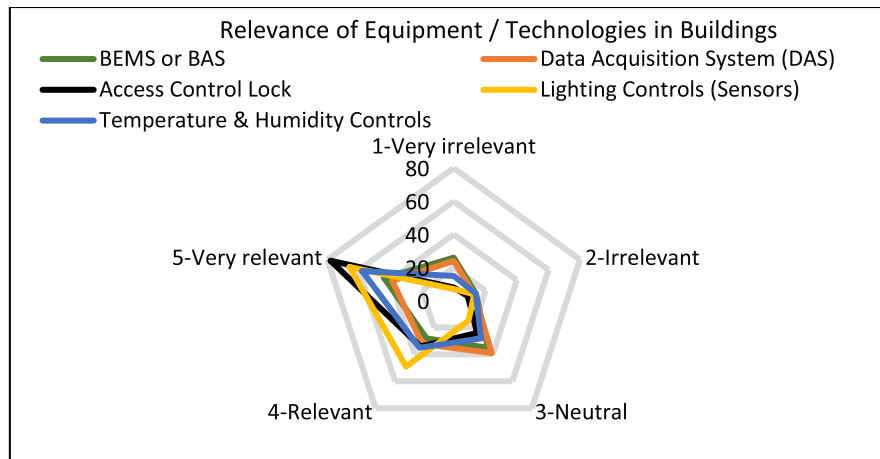


Figure 7.2: Relevance of Installed Technologies in Case Buildings

Detail analysis of data set on countries by countries basis revealed that BEMS and DAS are not seen as relevant technologies for BEM in Nigeria. 40.0% of Nigeria case buildings' respondents, agreed that BEMS (38.0%) and DAS (35.0%), are irrelevant. While 30.0% of them were neutral on the usefulness of these technologies (BEMS: 23.7% and DAS: 32.5%). It could observe that those that were neutral don't have the knowledge of the application of these equipment, hence not sure of its usefulness. Thus, confirms that such technologies are not installed on all the Nigeria case buildings.

Table 7.2: Usefulness of Installed Technologies in Buildings.

Usefulness of Installed Technologies in Buildings, based on 5-point Likert's scale: 1-Very Irrelevant; 2-Irrelevant; 3- Neutral; 4- Relevant & 5- Very Relevant.										
Answer Options	1	2	3	4	5	Wt. Agg. Relevant	Ranking	RIA: Relevant	Relative Index Analysis	RIA Ranking
Building Energy Management System (BEMS) or (BAS):	26	14	35	28	44	72	4	72	2,117	4
Data Acquisition System- DAS:	24	13	39	32	39	71	5	71	2,087	5
Access Control Lock:	8	9	24	34	78	112	2	112	3,293	2
Lighting Controls (Sensors):	7	13	15	49	66	115	1	115	3,381	1

The result indicated that LC-Sensor (RIA = 1<sup>st</sup>) and ACL (RIA = 2<sup>nd</sup>) are the most useful in both countries. THC (RIA = 3<sup>rd</sup>) was also useful, nevertheless, BEMS (RIA = 4<sup>th</sup>) and DAS (RIA = 5<sup>th</sup>) were adjudged the least significance for reducing BEU. This however, is due to the relatively unknown application of these technologies to the Nigeria respondents.

When compared on item by item basis, majority of respondents in Nigeria said BEMS/ BAS (SM = 2.72; SD = 1.36; skewness = 0.11; and kurtosis = -1.20) are very irrelevant as indicated

by its modal value (1.00). This is in variance with the UK's respondents (mode = 5.00), where majority said BEMS/ BAS (SM = 3.88; SD = 1.29; skewness = -0.88; and kurtosis = -0.30) are very relevant.

Majority of Nigerian respondents (mode = 3.00), are likewise neutral about the relevance of DAS (SM = 2.66; SD = 1.30; skewness = 0.14; and kurtosis = -0.96). Also, the equipment is not install in these buildings, hence the lack of awareness on application of these technologies. Thus, they perceived it as irrelevant. Whereas, the majority UK's respondents (mode = 5.00) identified the installations of these equipment (SM = 3.90; SD = 1.21; skewness = -0.94; and kurtosis = 0.03) in case buildings. Consequently, agreed that they very relevant.

Most respondents in both countries however, agreed that other investigated technologies are relevant. The results reveal they have same modal value (mode = 5.00) for other equipment: ACL, LC-Sensors and THCs. Data distribution also reveal that majority have the same median (4.00) and their distributions for both countries are negatively skewed.

## II. Technology Drives BEP

The study, also, investigated the theoretical claim that technologies help drives BEP based on occupants' perception. The result (Figure 7.3), indicates a general agreement that technologies help drive BEP.

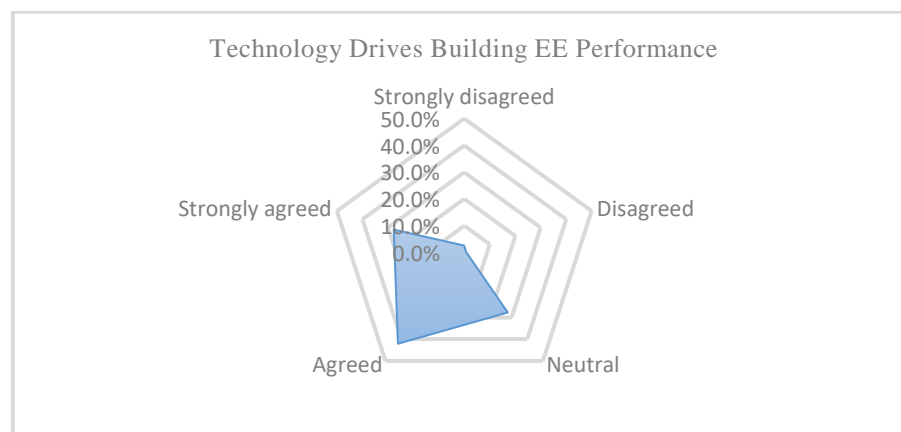


Figure 7.3: Responses on Technology as Driver for BEP.

The majority (69.8%) of the occupants agreed to this proposition. About a third of the respondents (27.6%) were neutral, and just very few (3.3%) who disagreed. The data

distribution statistics indicated a normal distribution curve with the same modal and median value of 4.00 and a SM (3.90). There were just little variances in the data set with SD (0.90) of approximate 1.00 but negatively skewed (-0.75) towards unanimous agreed on the proposition

### 7.2.3 Building Comfort and its EEP

Measurement of the perceived comfort of buildings' IAT for summer (dry) and winter (rainy) seasons is used as comfort metric. The study obtained occupants' comfort perception via the 5-point Likert's scale of -2 (cold) to +2 (hot). Hence, the thermal neutral scale was set at 3 = 0 based on study neutral temperature of 20<sup>0</sup>C (Nigeria) and 15.5<sup>0</sup>C (the UK).

Analysis (Table 7:3; Table 7:4 & Table 7:5), shows the respondents' aggregate rating (comfortable and very comfortable) as ranked; and compared with their relative index analysis (RIA) ranking for each building. Likewise, aggregate frequency for comfort was used to contextualise case buildings thermal performance based on standard expectation using  $-0.5 \leq PMV \leq +0.5$  or the PPD ( $\leq 10\%$ ) (Fanger, 1970), as thus:

Table 7:3: Perceived Comfort: IAT in summer (Dry) Season

Summer's (Dry Season) Indoor Air Temp. (IAT)		Valid N	Agg. Frequency: Comfortable	5- point Likert's Scale: 1 =Very uncomfortable; 2= Uncomfortable; 3= Neutral; 4= Comfortable & 5= Very comfortable					Ranking: Freq. Comfortable (Agg. %)	Relative Index Analysis	RIA Ranking
SN	Buildings	n	%	1	2	3	4	5			
	NGN:	69									
1	BLDG101	47	76.0	3	4	2	23	15	1	357.20	1
2	BLDG102	14	64.3	0	3	2	5	4	4	25.20	2
3	BLDG103	5	60.0	1	1	0	2	1	5	3.00	5
4	BLDG104	10	72.7	0	0	2	6	2	2	16.00	3
5	BLDG105	5	66.7	0	0	1	3	1	3	4.00	4
	UK:	70									
6	BLDG206	23	65.4	0	1	5	15	2	3	78.20	1
7	BLDG207	12	46.7	0	2	3	5	2	5	16.80	4
8	BLDG208	1	100.0	0	0	0	1	0	1	0.20	5
9	BLDG209	16	81.3	0	3	0	12	1	2	41.60	2
10	BLDG210	16	51.1	1	3	3	8	1	4	28.80	3



Table 7:4: Perceived Comfort: IAT in winter (Rainy) Season

Winter (Rainy Season) Indoor Air Temp. (IAT)		Valid N	Agg. Frequency: Comfortable	5- point Likert's Scale: 1 =Very uncomfortable; 2= Uncomfortable; 3= Neutral; 4= Comfortable & 5= Very comfortable					Ranking: Freq. Comfortable (Agg. %)	Relative Index Analysis	RIA Ranking
SN	Buildings	n	%	1	2	3	4	5			
	NGN:	70									
1	BLDG101	45	78.0	0	5	1	27	12	3	351.00	1
2	BLDG102	11	42.9	0	0	5	3	3	5	13.20	3
3	BLDG103	5	80.0	1	0	0	3	1	2	4.00	4
4	BLDG104	10	90.9	0	0	0	9	1	1	20.00	2
5	BLDG105	4	50.0	0	0	1	2	1	4	2.40	5
	UK:	76									
6	BLDG206	23	46.2	0	4	7	9	3	4	55.20	1
7	BLDG207	13	66.7	0	0	3	7	3	3	26.00	3
8	BLDG208	1	100.0	0	0	0	1	0	1	0.20	5
9	BLDG209	16	75.0	0	2	2	11	1	2	38.40	2
10	BLDG210	16	44.4	1	3	4	6	2	5	25.60	4

Table 7:5 NGN and UK Case Buildings' Comfort Rating Based on PMV

NGN and UK Case Buildings Comfort Rating Based on PMV: 5%, 10% & 50% @ PMV= 0, ±0.5 & ±1 respectively for Summer/Dry and Winter/ Rainy Seasons											
Summer / Dry Season	Bldg. 101	Bldg. 102	Bldg. 103	Bldg. 104	Bldg. 105	Bldg. 206	Bldg. 207	Bldg. 208	Bldg. 209	Bldg. 210	
Thermal Neutral PMV = 0 @5%	4.3	14.3	0.0	20.0	20.0	21.7	25.0	0.0	0.0	18.8	
10% @ PMV = ±0.5	44.6	28.6	20.0	80.0	80.0	82.6	50.0	100.0	56.3	50.0	
50% @ PMV = ±1	70.2	57.1	20.0	100.0	100.0	65.2	65.1	NA	62.5	50.0	
Winter/ Rainy Season	Bldg. 101	Bldg. 102	Bldg. 103	Bldg. 104	Bldg. 105	Bldg. 206	Bldg. 207	Bldg. 208	Bldg. 209	Bldg. 210	
Thermal Neutral PMV = 0 @5%	2.2	45.5	0.0	0.0	25.0	30.4	23.1	0.0	12.5	25.0	
10% @ PMV = ±0.5	51.1	72.7	60.0	90.0	75.0	52.2	82.6	100.0	68.8	43.8	
50% @ PMV = ±1	87.7	100.0	60.0	100.0	100.0	65.2	100.0	NA	75.0	50.0	

### I. Nigeria Case Buildings

The result for Bldg101 based on thermal neutrality (4.3% & 2.2%  $\leq$  5.0%), indicates poor thermal comfort for both seasons (Table 7:5). This is less than recommended PMV= 0 @5% for people who felt neutral about being comfortable or discomfort (Fanger, 1970). Also, an increase in the PMV from 0= PMV@ 5% to  $\pm 0.5$  (10%) and  $\pm 1$  (50%), revealed higher PMV (44.6 & 70.2% for the dry season, and 51.1% & 87.7% for rainy season) respectively. This show that HVAC is used in providing human comfort in the building. Hence, most participants perceived the building most comfortable (the IAT) in the dry season (76.0%; RIA =1<sup>st</sup>) and rainy season (78.0%; RIA= 1<sup>st</sup>) (Table 7:3 and Table 7:4).

Bldg102 thermal neutral (14.3% for dry season & 45.5% for rainy season  $>$  5.0%) is the best amongst case buildings in both season. Likewise, its PMV also increase (28.6%- dry and 72.7%- rainy seasons) with an increase in the PMV to  $\pm 0.5$  (10%). Findings indicate that

HVAC is used to provide comfort in satisfying more user; and it has better comfort performance in the rainy season than in the dry season based on PMV rating. Although, the frequency and RIA shows otherwise, but the difference is due to accuracy level for subjective measures judgement, which the PMV has better predictive power (ISO 7730:2005).

Case Bldg103 has poor thermal neutral result ( $0.0\% \leq 5.0\%$  for both seasons). But, it's PMV increased (20.0%- dry and 60.0%- rainy seasons) with an increase in the PMV to  $\pm 0.5$  (10%). Results for both PMV (20.0%- dry & 60.0% rainy season) and perceived comfortable frequency (60.0%-dry season & 80.0% rainy season), indicate better comfort performance in the rainy season for bldg103.

Case Bldg104 and Bldg105 have ( $20.0\% > 5.0\%$ ) good comfort, performance in summer season based on PMV neutrality criteria ( $PMV=0 @ 5.0\%$ ). Nonetheless, whilst, bldg104 has ( $0.0\% \leq 5.0\%$ ) poor thermal neutral result in winter, bldg105 ( $25.0\% > 5.0\%$ ) indicated a good result. Nonetheless, both buildings' PMV also increase to 80.0% for dry seasons; and to 90.0% (bldg104) & 75.0% (bldg105) for rainy season, as the PMV increased to  $\pm 0.5$  (10%). The result also agreed with respondent's perceived comfort for IAT; 72.7% (dry season), and 90.9% (rainy season). It indicates improved comfort and that both building are more comfortable in the rainy season. This could be due to the use of natural ventilation that provided wider range of comfort for more users.

### *I. UK Case Buildings*

Among the UK case buildings, Bldg206 was considered the most comfortable ( $RIA=1^{st}$ ), in terms of IAT in both seasons (summer and winter). The result (Table 7:3 and Table 7:4), reveals that most users, 65.4% (summer) and 46.2% (winter) claimed it was comfortable in both seasons. This result concurs with the PMV criteria standard ( $PMV=0 @ 5.0\%$ ), as Bldg206 exhibit good thermal neutral result ( $21.7\% \& 30.4\% \geq 5.0\%$ ), for both seasons (Table 7:5). Its PMV also increase (82.6%- dry and 52.2%- rainy seasons) with an increase in the PMV to  $\pm 0.5$  (10%). Also, it agreed with majority of respondents' perception (73.9%) that bldg206 is more comfortable in summer period.

Bldg207 also exhibits good thermal neutral result ( $25.0\% \geq 5.0\%$ ;  $65.3\% \geq \pm 0.5$  and  $65.1 \geq \pm 1$ ) in summer, and ( $23.1\% \geq 5.0\%$ ;  $82.6\% \geq \pm 0.5$  and  $100.0 \geq \pm 1$ ) in the winter. The PMV result agreed that it has better comfort in winter (about 66.7%) than in summer season (46.7%), and

ranked 3<sup>rd</sup> on overall comfort compared within cases. Whereas, Bldg208 has poor thermal neutral result ( $0.0\% \leq \text{PMV}@5.0\%$ ), for both season. It is the least comfortable buildings amongst the UK cases, as its IAT ranked 5<sup>th</sup> (RIA) in terms of comfort for both seasons. Though, it was just an opinion of one out of the two staff, result suggest that its comfort is driven by use of HVAC.

Result for Bldg209's showed different thermal neutral results ( $0.0\% \leq \text{PMV}@5.0\%$ ), which is considered poor in the summer and ( $12.5\% \leq \text{PMV}@5.0\%$ ), good in the winter. Although, its IAT was perceived comfortable for both seasons (summer= 81.3%; winter= 75.0%). Also, improved comfort for both seasons was achieved through the increase in its PMV to  $\pm 0.5$  (10%) and  $\pm 1$  (50%), which aided higher PMV (56.3% & 62.5% for summer season, and 68.8% & 75.0% for winter season) respectively. This agreed with users ranking it 2<sup>nd</sup> for both seasons within cases, making it the 2<sup>nd</sup> most comfortable building.

Result for Bldg210's revealed good thermal performance ( $18.8\% \& 35.0\% \leq \text{PMV}@5.0\%$ ), for both seasons. However, increase of its PMV to  $\pm 0.5$  (10%) and  $\pm 1$  (50%), indicated a marginal comfort improvement (50.0% for the summer season, and 43.8% & 50.0% for winter season) respectively. It explained why the IAT is perceived as 2<sup>nd</sup> least comfortable after bldg208 amongst cases. Result agreed with the respondents' comfort rating of 56.3% (summer), and 44.4% (winter), for its IAT.

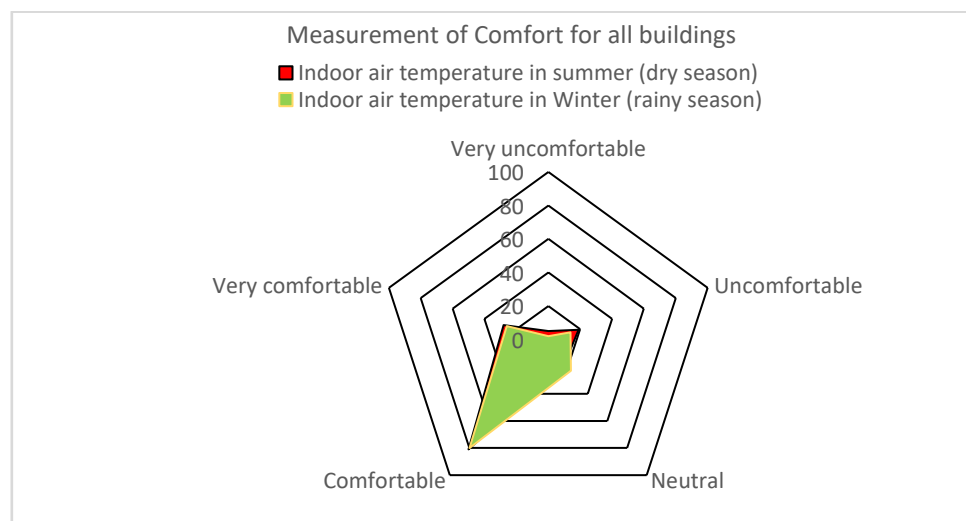


Figure 7.4: NG-UK Case Buildings' Perceived Comfort- IAT

## II. NG-UK Comparison

The result (in Figure 7.4), indicates that more than 60.0% of the occupants perceived the IAT of these buildings comfortable in both seasons in the two countries. It indicated case buildings meet the requirement of thermal neutral of  $PMV = 0@5\%$ ;  $\pm 0.5$  (10%) and  $\pm 1$  (50%). However, the UK buildings result indicate better thermal comfort design than Nigeria buildings based  $PMV = 0@5\%$  criteria.

Analysis indicated, case buildings (Nigeria & UK), are generally more comfortable in the rainy (winter) season than in the dry (summer) season. Whilst, HVAC usage in these buildings aided their thermal comfort improvement via increment of their PMV to  $\pm 0.5$  and  $\pm 1$  comfort neutral zone (Akanke, 2010).

#### 7.2.4 Occupant's Energy Consumption Behaviour

The POE survey investigated occupants perceived behavioural control (PBC); habit /attitude; awareness of environmental norms; and willingness/ concerns (indicated intension) using sampled buildings. It aims to examine variation in data collected, and determine level of user's energy behaviour between countries.

##### *I. Occupant's BEU Perceived Behaviour Control (PBC)*

The respondents (N = 166) were asked to indicate the level of their perceived control on case building installed services. Based on three choices (no control; neutral; and having control options) on each variables users' PBC is obtained. The result in case countries analysis of occupants' helps reveal the influences of occupant behaviour on case BEU.

Occupants of Nigeria case buildings have the strongest PBC on shading (64.7%; RIA = 1<sup>st</sup>), and lighting (57.8%; RIA = 2<sup>nd</sup>). The result indicates that lighting energy used is influenced by more than half of the occupants. However, the respondents have no control on other variables, hence ranking for no control was high in ranking index.

More than half of the respondents do not influence: heating (60.3%; RIA ranking = 7<sup>th</sup>); noise level (58.8%; RIA = 6<sup>th</sup>); and cooling (55.9%; RIA = 5<sup>th</sup>). While more than a third of the occupants have no control on ventilation (44.1%; RIA = 4<sup>th</sup>) and daylight (37.9%; RIA = 3<sup>rd</sup>). It indicates that users in tropical region have no dealing with heater/ radiators. However, since heating is not installed in case buildings, thus, no control on it.

The UK case result is significantly different in pattern from the Nigeria case. A hundred percent of the UK's respondents have PBC on all variables. More than 70.0% of the respondents influences shading (81.5%; RIA = 2<sup>nd</sup>); BEU for cooling (81.7%; RIA = 1<sup>st</sup>); and lighting (72.8%; RIA = 3<sup>rd</sup>). Similarly, more than half of them have strong PBC on ventilation (65.8%; RIA = 4<sup>th</sup>), and daylight factor (51.2%; RIA = 5<sup>th</sup>), in these buildings. While, more than a third of the respondents have a strong PBC on noise level (46.1%; RIA = 6<sup>th</sup>), and heating (42.7%; RIA = 7<sup>th</sup>), consequently, influences on heating energy use of the buildings is low.

## II. Energy Efficiency Habits.

The ranking of respondents' EE habits/ attitudes in case buildings were obtained through frequency of those that agreed and RIA for comparison (Table 7:6 and Table 7:7). Further investigation into variances in pattern, necessitated detailed analysis on occupant's attitude towards EE for each country.

Majority of Nigeria respondents (63.6%), agreed to have the attitude of switching-off (Table 7:6). The attitude of I-switch-off-often generally (63.6%; RIA = 1<sup>st</sup>) ranked first amongst other attitudinal variables. The respondents that switch-off-sometimes (34.4%; RIA = 2<sup>nd</sup>), came next in a similar pattern to the general result obtained earlier. Whilst only few of the respondents (16.3%; RIA = 3<sup>rd</sup>) agreed that they don't switch-off generally.

Table 7:6 Occupants' Energy Efficiency Habits/ Attitudes (NIG)

Case Buildings' Occupants in NIG	Valid N	Ranking of energy efficiency habits based on 5-point Likert's Scale: 1= strongly disagreed; 2= disagreed; 3= neutral; 4= agreed & 5= strongly agreed.					Agg. Frequ ency: Agree d	Rankin g: Freq. Agg. Agreed (Valid %)	Relativ e Index Analys is	RIA RANKI NG
		1	2	3	4	5	Valid %			
I switch-off often: Generally	66	3	7	14	29	13	63.6	1	554	1
I switch-off some times: Generally	64	10	9	23	19	3	34.4	2	282	2
I don't switch-off: Generally	62	20	19	13	6	4	16.3	3	124	3

Same result was obtained from the UKs' respondents (Table 7:7). Many of the respondents (about 68.3%), agreed that they have the attitude of switching-off. Also, the attitude of I switch-off often generally (68.3%; RIA = 1<sup>st</sup>) ranked first amongst other attitudinal variables. The

group that switch-off sometimes (59.8%; RIA = 2<sup>nd</sup>), was next in ranking, whilst only a few of the respondents (26.3%; RIA = 3<sup>rd</sup>) agreed that they don't switch-off generally.

Table 7:7: Occupants' Energy Efficiency Habits/ Attitudes (UK)

Case Buildings' Occupants in UK	Valid N	Ranking of energy efficiency habits based on 5-point Likert's Scale: 1= strongly disagreed; 2= disagreed; 3= neutral; 4= agreed & 5= strongly agreed.					Agg. Frequency: Agreed	Ranking : Freq. Agg. Agreed (Valid %)	Relative Index Analysis	RIA RANKING
Answer Options	n	1	2	3	4	5	Valid %			
I switch-off often: Generally	79	10	7	8	31	23	68.3	1	853	1
I switch-off some times: Generally	77	12	10	9	33	13	59.8	2	708	2
I don't switch-off: Generally	76	35	12	9	12	8	26.3	3	304	3

More respondents in the UK (68.3%) compared to those in Nigeria (63.6%), have the attitude of: I switch-off often. This only a slight marginal difference (7.4%), hence it could be concluded that occupants' in both countries have the habit of switching-off-often.

### III. Energy Behaviour Intentions

Intention plays a very important role in understanding occupants' energy behaviour. Our purpose of doing certain things, or resolve to act in certain way help shape our habits. Hence, the current study seeks to identify the underlying factors that influence the occupant energy use behaviour. Respondents in both countries (n = 143) indicated their energy behaviour intentions based on 5-point Likert's scale on intention variables: energy conservation; building energy cost reduction; and reducing CO<sub>2</sub> emissions from buildings.

The result for Nigeria (Table 7:8), indicates a switching-off habit driven by the motive of conserving energy use. About 77.7% (RIA = 1<sup>st</sup>), ranked this motive 1<sup>st</sup> amongst these variables. While a third, 56.7% (RIA= 2<sup>nd</sup>) of them, reported that the same habit is being influenced by the intention of reducing energy cost of building. Whilst, the intention of reducing CO<sub>2</sub> emissions from buildings was the least accepted (24.0%; RIA = 3<sup>rd</sup>), amongst motives underlying occupants habit of switching-off.

Table 7:8: Occupants' Energy Behaviour Intentions (NIG)

Case Buildings' Occupants in NIG	Valid N	Ranking of energy behaviour intentions based on 5-point Likert's Scale: (1= SD- strongly disagreed; 2= D- disagreed; 3= N- neutral; 4= A- agreed & 5= SA- strongly agreed)					Agg. Frequency: Agreed	Ranking: Freq. Agg. Agreed (Valid %)	Relative Index Analysis	RIA RANKING
Answer Options	n	1	2	3	4	5	Valid %			
*I switch-off to conserve energy	67	2	7	6	32	20	77.7	1	697	1
*I switch-off to reduce this building energy cost	67	3	11	15	26	12	56.7	2	509	2
*I switch-off to reduce carbon emissions from this building	66	4	14	20	17	11	42.5	3	370	3

UK case buildings' result (Table 7:9), indicate a clearly different pattern from Nigeria respondents' results. Most participants shared equal preference for conserve energy (63.7%; 1<sup>st</sup>) and reduce building energy cost (63.7%; 1<sup>st</sup>). They considered the two motives equal and important for cultivating the habit of switching-off. Whereas, the motive of reducing CO<sub>2</sub> emissions from buildings (42.9%; 3<sup>rd</sup>), in switching-off is considered the least.

Table 7:9: Occupants' Energy Behaviour Intentions (UK).

Case Buildings' Occupants in UK	Valid N	Ranking of energy behaviour intentions based on 5-point Likert's Scale(1= SD- strongly disagreed; 2= D- disagreed; 3= N- neutral; 4= A- agreed & 5= SA- strongly agreed)					Agg. Frequency: Agreed	Ranking: Freq. Agg. Agreed (Valid %)	Relative Index Analysis	RIA RANKING
Answer Options	n	1	2	3	4	5	Valid %			
*I switch-off to conserve energy	77	5	11	12	28	21	63.7	1	755	1
*I switch-off to reduce this building energy cost	77	8	11	9	29	20	63.7	1	755	1
*I switch-off to reduce carbon emissions from this building	77	13	12	19	19	14	42.9	3	508	3



### 7.2.5 Non-Parametric Tests: EE Habits and Users' Intention

#### *I. Energy Efficiency Habits*

The current study investigates the relationship between the variables of energy habit/ attitude to validate and delineate occupants' habits/ attitudes. The Spearman's rho ( $r_s$ ) correlation coefficient two-tailed test for ranking data was applied. The tests were performed on responses in both countries for: 'I switch-off often: generally'; 'I-switch-off-sometimes: generally'; and 'I-don't-switch-off: generally'.

The result for the Nigeria respondents revealed negative, weak relationships (p-value significantly  $> 0.05$  at 5% significance level). The test on 'I switch-off-often' to 'switch-off-sometimes' ( $r_s = -0.165$ ;  $p = 0.201 > 0.05$ ; and  $n = 62$ ), has negative linear correlation and too weak to be affiliated.

The result for test on 'I switch-off often to 'I don't switch-off' shows that they have a strong negative linear correlation. The Spearman' rho ( $r_s = -0.660^{**}$ ;  $p = 0.000$ ), confirmed that these two variables are strongly but negatively affiliated.

Further test on 'I switch-off sometimes to 'I don't switch-off. The Spearman's (rho  $r_s = -0.053$   $p = 0.683$ ), indicated a negatively weak and insignificance association.

UK's respondents' habits were further examined for possible association. Results indicate that the test of the relationship between 'I switch-off often': 'switch-off sometimes' ( $r_s = 0.121$ ;  $p = 0.299$ ), is positive, but weak insignificant affiliation. The Spearman's rho at 5% level of significance, indicated a positive and too weak hence, are not associated.

Spearman's rho test performed on 'I switch-off often: 'I don't switch-off', however, reveal a strong negative linear correlation like the Nigeria result. Result ( $r_s = -0.485^{**}$ ;  $p = 0.000$ ), at 1% level of significance confirmed that the two variables are mutually exclusive too.

Finally, result for test on 'I switch-off sometimes: 'I don't switch-off ( $r_s = 0.071$   $p = 0.543$ ), indicates a positive weak association unlike the Nigeria result. The  $p = 0.543$  at 5% level of significance, is insignificance, thus they are not associated.



## *II. Energy Behaviour Intentions*

The study further investigated the degree to which any of the two intention variables have a linear relationship. Their comparison could give an indicative sequence of user's thoughts processes; and prioritisation of intention variables for examining actual energy use habitus.

The possible linear relation for Nigeria's responses on 'I switch-off to: conserve-energy' and 'reduce-building-energy-cost (BEC)' indicated a positively strong and significant correlation. Result reveals positive Spearman's rho ( $r_s = .753^{**}$ ;  $p = 0.000 < 0.01$ ;  $n = 67$ ) test at 1% level of significance.

Result of correlation on 'I switch-off to: conserve-energy' and 'reduce-building-CO<sub>2</sub> emissions (BCO<sub>2</sub>E)' reveal similar relationship. The Spearman's rho ( $r_s = 0.529^{**}$ ) at 1% level of significance, also showed strong positive linear relation.

Result of 'I switch-off to: reduce-building-energy-cost' and 'reduce-building-CO<sub>2</sub> emissions' also indicated similar relationship. The Spearman's rho ( $r_s = 0.710^{**}$ ;  $p = 0.000$ ) at 1% level of significance showed a strong positive linear relation. Their affiliation is also significant ( $p < 0.01$ ).

The UK's response was also tested for possible linear association. The correlation result on 'I switch-off to: conserve-energy' and 'reduce-building-energy-cost' is positively significant. Its Spearman's correlation coefficient ( $r_s = 0.653^{**}$ ;  $p = 0.000$ ) at 1% level of significance indicates strong positive relation.

The result of relationship between 'I switch-off to: conserve-energy' and 'reduce-building-CO<sub>2</sub> emissions' reveal similar affiliation. The Spearman's rho ( $r_s = 0.610^{**}$ ;  $p = 0.000$ ) at 1% level of significance, also reveals strong positive linear relation.

The result of 'I switch-off to reduce building energy cost' and 'I switch-off to reduce building CO<sub>2</sub> emissions' reveals stronger relationship. The Spearman's rho ( $r_s = 0.744^{**}$ ;  $p = 0.000$ ) at 1% level of significance showed a strong positive linear relation.

## *III. User's Habits/ Attitude and Intentions*

The study investigated occupants' habits/ attitudes and their intentions as propelling factor of energy behaviour. Possible correlation between pair of factors that lead to plausible prepositions based on strong linear relations is employed.

The Pearson Chi-Squared tests based on likelihood values and Cramer's V tests ( $\alpha = 0.050$ ; DF = 16), were performed on the following paired variables (*Table 7:10*):

- I switch-off often\* I switch-off to conserve energy
- I switch-off often \* I switch-off to reduce this BEC
- I switch-off often \* I switch-off to reduce BCO<sub>2</sub>E
- I switch-off sometimes \* I switch-off to conserve energy
- I switch-off sometimes \* I switch-off to reduce BEC
- I switch-off sometimes \* I switch-off to reduce BCO<sub>2</sub>E
- I don't switch-off \* I switch-off to conserve energy
- I don't switch-off \* I switch-off to reduce this BEC
- I don't switch-off \* I switch-off to reduce BCO<sub>2</sub>E

Table 7:10: User's Habits/ Attitudes and Intentions

Cross Tab: Case processing summary								
Chi-Square Tests								
	Valid N	expected count < 5	$\alpha$ -value	Likelihood Ratio;		Cramer's V value ;		Spearman $r_s$
				Value; P-value	Value; P-value	Value; P-value	P-value; 2-tailed sign	df
I switch-off often *I switch-off to conserve energy:	142	60.0%	.050	112.422; .000	.515; .000	.657; .000 <sup>c</sup>		16
I switch-off often* I switch-off to reduce bldg. energy cost:	142	64.0%	.050	103.285; .000	.463; .000	.536; .000 <sup>c</sup>		16
I switch-off often* I switch-off to reduce bldg. CO <sub>2</sub> emissions:	140	56.0%	.050	100.668; .000	.486; .000	.490; .000 <sup>c</sup>		16

Result for test on 'I switch-off often' & 'I switch-off to conserve-energy', indicates a positive correlation with likelihood ratio (112.422;  $p = 0.000$ ). The Cramer's V (C's value= 0.515;  $p = 0.000$ ), for reporting for more than two categories also indicate a strong relationship. A Cramer's value ranges from 0 (being no relationship) to 1 (being strong relationship). Whilst, Spearman's ranked correlation ( $r_s = 0.657$ ;  $p = 0.000^c < \alpha = 0.05$ ), at the 5 % level of significance, shows a strong positive correlation hence, they are associated.

Test result on 'I switch-off often' & 'I switch-off to reduce BEC', further reveals positive association. The likelihood ratio (103.285) and the Cramer's V (.463), also indicates a moderate relationship. Whilst, the Spearman's ranked correlation ( $r_s = 0.536$ ) at the 5% level of significance, confirmed a strong positive correlation hence, they are associated.

The third test on 'I switch-off often' & 'I switch-off to reduce BCO<sub>2</sub>E', also indicated positive linear relation. The likelihood ratio (100.668) and the C's value (0.486), likewise reveal a strong association. Whilst the Spearman's rho ( $r_s = 0.486$ ) at the 5% level of significance, confirms a smooth moderate positive correlation hence, they are affiliated.

Tests results for other paired variables indicate both positive and negative weak associations that are non-significant. The test on 'I don't switch-off' & 'I switch-off to conserve energy' with C's value (0.364) and  $r_s$  (-0.468) at 5% level of significance, indicates a negatively strong and significant association. Whilst other results indicate non-significant associations at 5% level of significance as thus:

- 'I switch-off sometimes' & 'I switch-off to conserve energy' has C's value (0.285;  $p = 0.000$ ) and  $r_s = (0.003; p = 0.975^\circ)$ .
- 'I switch-off sometimes' & 'I switch-off to reduce-BEC' has C's value = 0.280;  $p = 0.000$ ) and  $r_s (0.171; p = 0.046^\circ)$ .
- 'I switch-off sometimes' & 'I switch-off to reduce BCO<sub>2</sub>E' has C's value (0.337;  $p = 0.000$ ) and  $r_s (0.287; p = 0.001^\circ)$ .
- 'I don't switch-off' & 'I switch-off to reduce this building energy cost' has C's value (0.302;  $p = 0.000$ ); and  $r_s (-0.345; p = 0.000^\circ)$ , and
- 'I don't switch-off' & 'I switch-off to reduce building carbon emissions' has C's value (0.285;  $p = 0.000$ ) and  $r_s (-0.276; p = 0.001^\circ)$ .

#### 7.2.6 FM as a Useful Tool for Reducing BEU

The study investigates the usefulness of Facilities Management in the management of BEU and BEP. The participants ( $N = 166$ ), were asked to express their opinion based on 5-point Likert's scale.

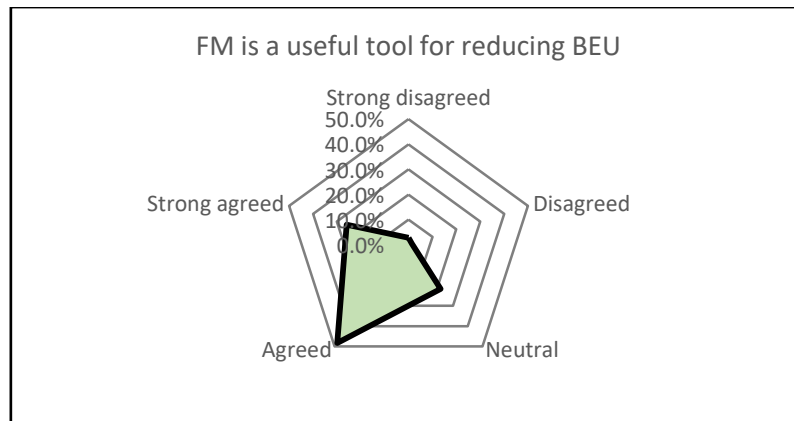


Figure 7.5: Usefulness of FM as tool for reducing BEU

About a third (25.9%) of the occupants strongly agreed, while almost half of the (48.3%), agreed to the usefulness of FM in reducing BEU (Figure 7.5). The data distribution reveals normal distribution curves for both countries ( $n = 143$ ), Nigeria ( $n = 66$ ), and the UK ( $n = 78$ ). Its statistics indicate general agreement as the data from both countries have the same median, range and modal value (4.00). It also has SM (3.93) with SD < 1.00 (0.89); including negative skewedness (-0.97) and a positive kurtosis (1.65). The response data point to strong agreement to the usefulness of FM in driving down BEU.

Further analysis shows that more occupants in the UK (84.0%) than in Nigeria (66.7%), agree to the usefulness of FM as a tool for reducing energy use in building. Whilst, fewer occupants who are neutral on this view in the UK (12.8%) than in Nigeria (31.8%).

#### 7.2.7 Maintenance & Energy Retrofit as Drivers for EEP.

The study further explored the effectiveness of planned & routine maintenance, and energy retrofits as drivers for BEP. The 5-point Likert's scale was used to obtain a respondents' opinion. The result (Figure 7.6) for both countries, reveals that majority (about 74.7%) of respondents viewed maintenance and retrofit as propelling factor for driving BEP. However, < a third (22.5%) are neutral, while < 3.0% (2.7%) of occupants disagreed on the subject matter.

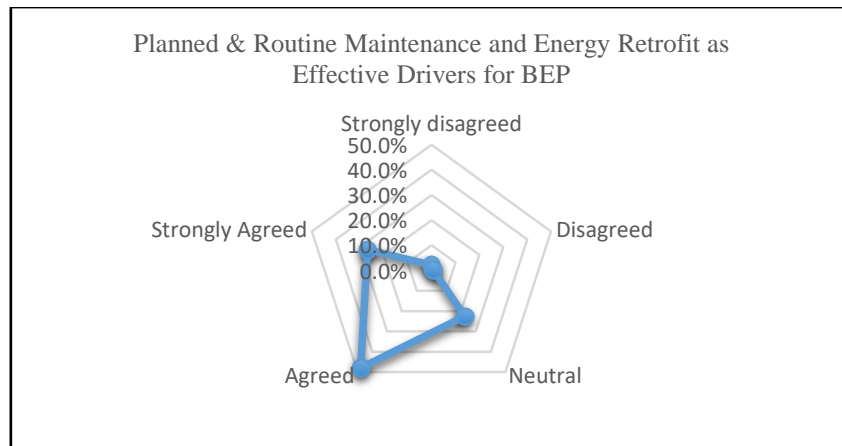


Figure 7.6: Maintenance & Energy Retrofit as Drivers for BEP

Precisely, about a third (26.8%) strongly agreed, and almost another half of the occupants (47.9%) agreed. However, the data distribution curves result showed strong agreement on Maintenance & Energy Retrofit as drivers for BEP. The result reveals normal distribution curves for both countries ( $n = 142$ ); Nigeria ( $n = 66$ ) and the UK ( $n = 78$ ). Its statistics reveal that both countries have the same median, range and modal value (4.00). The general result also has SM (3.96) with SD < 1.00 (0.85); negative skewedness (-0.86) and a positive kurtosis (1.54).

Further analysis on responses from each country, reveals distinct levels of agreement. More occupants in the UK (84.6%) than in Nigeria (63.7%), agreed on Maintenance & Energy Retrofit as drivers for BEP. Those with a neutral view on the study question are more in Nigeria (34.8%), than in the UK (11.5%).

#### 7.2.8 Assessment & Benchmarking as Drivers for Reducing BEU and BEC

The current study further investigated the option of regular energy audit and benchmarking as technical solution for reducing BEU and cost. The opinion of the occupants was obtained through the 5-point Likert's scale. Largely, the result for both countries (Figure 7.7), reveals that majority of users (about 79.7%), regards energy assessment and benchmark as drivers for reducing BEU and BEC. Whilst, < a third (16.1%) are neutral and < 5.0% (4.2%) of respondents reasoned otherwise.

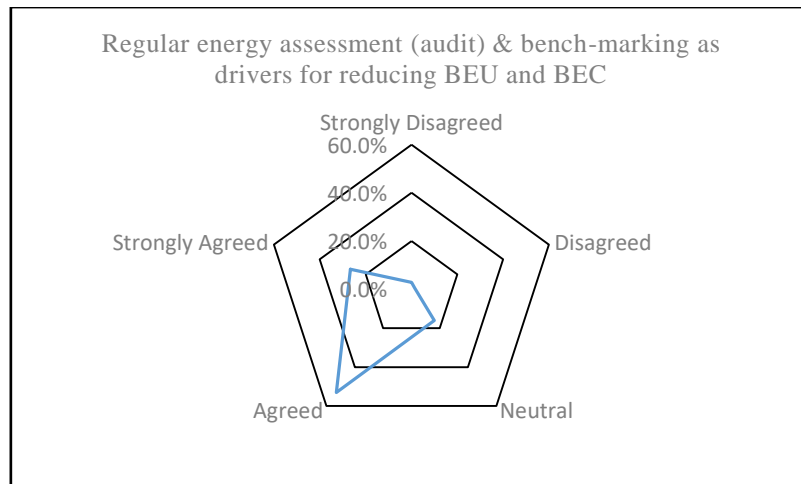


Figure 7.7: Assessment and Benchmark as drivers

Almost a third (26.6%) of participants strongly agreed, and another more than half of them (53.1%) agreed to the study variable. The distribution curves' result reveals normal distribution curves for both countries (n = 143); Nigeria (n = 66) and the UK (n = 78). Both countries have the same median, range and modal value (4.00). They have SM (3.99) with SD < 1.00 (0.86); negative skewedness (-1.2) and a positive kurtosis (2.50). The result exhibited strong agreement for energy assessment and benchmark as drivers for reducing BEU and cost.

Each country's data set reveals greater percent of occupants in the UK (85.9%) than in Nigeria (75.8%), who regarded energy assessment and benchmark as drivers for reducing BEU and BEC. Whilst, those that were neutral are more in Nigeria (21.2%), than in the UK (10.3%). The UK's respondents formed greater percent of those who agreed strongly with this study variable than their Nigeria counterparts.

#### 7.2.9 Environmental Norms: Occupants' Awareness and Concerns

##### I. Global Environmental Issues (Norms): Awareness

Occupants' perceived level of awareness in case buildings (Nigeria and UK) was obtained (Table 7:11 and Table 7:12). A 5-point Likert's scale was used to rank perceived awareness. The data were analysed based on the aggregate of awareness (valid percent) frequency and relative index analysis.

Nigeria data analysis result (Table 7:11), indicates EE (83.4%; RIA= 1<sup>st</sup>), ranked first in level of awareness. Likewise, climate change (CCH) (70.1%; RIA= 2<sup>nd</sup>); global warming (68.6%; RIA= 3<sup>rd</sup>); and sustainability (60.6%; RIA= 4<sup>th</sup>) recorded a prominent level of awareness among participants. Also, CO<sub>2</sub> emissions (56.7%; RIA= 5<sup>th</sup>), carbon footprint (56.8%; RIA= 6<sup>th</sup>), and BEP (50.7%; RIA= 7<sup>th</sup>) received a satisfactory level of awareness; but comparatively lower in descending awareness level.

Table 7:11: Global environmental norms Awareness in relation to BEU- NIG.

Global Environmental Issues (Norms): NIG	Valid N	Awareness in relation to BEU based on Likert's scale: 1= not fully aware; 2= not aware; 3= neutral; 4= aware; & 5= fully aware.					Agg. Frequency: Awareness	Ranking: Freq. Agg. Awareness	Relative Index Analysis	RIA Ranking
		n	1	2	3	4	5	Valid %		
Answer Options										
Climate Change	67	2	10	8	37	10		70.1	2	630
Global Warming	67	4	8	9	36	10		68.6	3	616
Sustainable Development	66	2	6	18	31	9		60.6	4	528
Carbon Dioxide Emission	67	3	14	12	31	7		56.7	6	509
Energy Efficiency	66	1	5	5	45	10		83.4	1	726
Carbon Footprint	67	3	12	14	32	6		56.8	5	509
Building Energy Efficiency Performance (BEEP)	67	1	13	19	27	7		50.7	7	456

The analysed data set (Table 7:12) for the UK's participants, indicated slight variance from the Nigeria case. The result shows that climate change and global warming have an equal level of awareness. Almost ninety percent of respondents are aware of CCH (85.5%; RIA = 1<sup>st</sup>) and global warming (85.5%; RIA = 1<sup>st</sup>). The level of awareness on EE (83.8%; RIA = 3<sup>rd</sup>); sustainable development (82.9%; RIA = 4<sup>th</sup>); and CO<sub>2</sub> emissions (82.4%; RIA = 5<sup>th</sup>), came next in decreasing order of hierarchical awareness. However, BEP (72.0%; RIA = 6<sup>th</sup>), and carbon footprint (50.7%; RIA = 7<sup>th</sup>), are low on awareness level.

Table 7:12: Global Environmental Norms: Awareness in relation to BEU- UK.

Global Environmental Issues (Norms): UK	Valid N	Awareness in relation to BEU based on Likert's scale: 1= not fully aware; 2= not aware; 3= neutral; 4= aware; & 5= fully aware.					Agg. Frequency: Awareness	Ranking: Freq. Agg. Awareness	Relative Index Analysis	RIA Ranking
		n	1	2	3	4	5	Valid %		
Answer Options										
Climate Change	76	2	4	5	39	26		85.5	1	988
Global Warming	76	4	5	2	38	27		85.5	1	988
Sustainable Development	76	2	5	6	39	24		82.9	4	958
Carbon Dioxide Emission	74	3	5	5	36	25		82.4	5	903
Energy Efficiency	74	2	7	3	39	23		83.8	3	918
Carbon Footprint	75	4	16	17	23	15		50.7	7	570
Building Energy Efficiency Performance (BEEP)	75	2	8	11	33	21		72.0	6	810

This is a slight departure from the Nigeria results where energy efficiency is highest on the awareness level.

## II. Global Environmental Issues: Concerns and Willingness for a Change

The POE survey likewise investigated respondents' willingness to change to energy efficient habits based on concerns for global environmental issues. The respondents from both countries (N= 166; valid= 140) were also asked to indicate based concerns for CO<sub>2</sub> emissions via BEU, their willingness for the study variables. Their perceived willingness (1= not fully concerned; 2= not concerned; 3= neutral; 4= concerned; and 5= fully concerned) was ranked (Table 7:13 and Table 7:14). Data were analysed based on the aggregate of awareness (valid percent) frequency; relative index analysis; and a ranking of variables.

Table 7:13: Global Environmental Norms: Concerns in relation to BEU- NIG.

Emissions from Buildings Energy Use: NIG	Valid N	Base on global concern for Emissions from BEU, indicate your willingness: Likert's scale: 1= not fully concerned; 2= not concerned; 3= neutral; 4= concerned; & 5= fully concerned.					Agg. Frequency: Concerned	Ranking: Freq. Agg. Concerned	Relative Index Analysis	RIA Ranking
		1	2	3	4	5				
Answer Options	n						Valid %			
*Willingness to change to more energy efficient Habit	67	2	1	9	38	17	82.1	1	737	1
*Willingness to Reduce Carbon footprint of this building	66	3	3	14	31	15	69.7	4	607	4
*Willingness to Reduce this building's energy Consumption	66	3	1	12	33	17	75.8	3	660	3
*Willingness to reduce Global warming	65	2	1	10	33	19	80.1	2	676	2

The results for Nigeria and United Kingdom revealed similar pattern with the general result. Result of Nigeria cases (Table 7:13), indicate more than eighty percent of the participants are willing to change to energy efficient habit (82.1%; RIA = 1<sup>st</sup>). About eighty percent (the respondents) are willing to reduce: global warming (80.1%; RIA = 2<sup>nd</sup>) and BEU (75.8%; RIA = 3<sup>rd</sup>). Whilst, seventy percent (participants) is willing to reduce building's carbon footprint (69.7%; RIA = 4<sup>th</sup>), which is the least in the hierarchy of concerned for environmental norms.



Table 7:14: Global Environmental Norms: Concerns in relation to BEU- UK.

Emissions from Buildings Energy Use: UK	Valid N	Base on global concern for Emissions from BEU, indicate your willingness: Likert's scale: 1= not fully Concerned 2= not concerned; 3= neutral; 4= concerned; & 5= fully concerned.					Agg. Frequency: Concerned	Ranking: Freq. Agg. Concerned	Relative Index Analysis	RIA Ranking
		1	2	3	4	5				
Answer Options	n						Valid %			
*Willingness to change to more energy efficient Habit	78	1	3	6	35	33	87.2	1	1061	1
*Willingness to Reduce Carbon footprint of this building	79	1	6	11	35	26	77.2	4	964	4
*Willingness to Reduce this building's energy Consumption	78	1	7	8	30	32	79.5	3	967	3
*Willingness to reduce Global warming	77	1	5	5	31	35	85.8	2	1016	2

UK's response data (Table 7:14), result reflected the same hierarchy of willingness to change with the Nigeria's case. The preference for energy efficient habit (87.2%; RIA = 1<sup>st</sup>), turned out to be the most chosen concerns. Eighty percent and above (participants) are willing reduce global warming (85.8%; RIA = 2<sup>nd</sup>), and BEU (79.5%; RIA = 3<sup>rd</sup>). Whilst about eighty percent of them are willing to reduce building carbon footprint (77.2%; RIA = 4<sup>th</sup>). Hence, it came as the least concerns on environmental norms.

#### 7.2.10 Non-Parametric Test: EE Behaviour and Environmental Norms

The results on occupants' energy behaviour and awareness of environmental issues have validated respondents' awareness level and their concerns/ willingness. Still, several doubts on how each factor influences one another have risen (as expressed below); and the possible reasons why each relationship exists, was explored through further test using Chi-Square statistics as follows:

Table 7:15, indicates the result of Chi-Square tests on paired variables based on these questions:

- Can awareness on climate change (CCH) inform the willingness to change to more EE habit?
- Does awareness on CCH inform the willingness to reduce global warming?
- Can awareness on CCH inform the willingness to reduce BEU?
- Can awareness on carbon emissions inform the willingness to reduce a building's carbon footprint (BCF)?

Table 7:15: Cross Tab: Environmental Issues- Awareness and Willingness/ Concerns.

Case processing summary							
	Chi-Square Tests						
	Likelihood Ratio; Cramer's V value ; Spearman $r_s$						
	Valid N	expected count < 5	$\alpha$ -value	Value; P-value	Value; P-value	P-value; 2-tailed sign	df
Climate change*							
EE Habits:	140	72.0%	.050	60.952; .000	.356; .000	.512; .000 <sup>c</sup>	16
Climate change*							
reduce Global warm.:	137	72.0%	.050	44.156; .000	.319; .000	.452; .000 <sup>c</sup>	16
Climate change*							
reduce BEU:	139	72.0%	.050	52.190; .000	.322; .000	.449; .000 <sup>c</sup>	16
CO <sub>2</sub> emissions*							
Red. Carbon footprint:	137	54.0%	.050	48.022; .000	.312; .000	.426; .000 <sup>c</sup>	16

The results (Table 7:15), reveal significantly positive linear correlations for all the tests. The test on awareness of CCH & willingness to change to EE habit indicates the C's value (0.356) and  $r_s$  (0.512) are significant. It's confirmed a smooth and strong positive correlation hence, they are affiliated. Likewise, other results: awareness of CCH & willingness to reduce global warming shows C's value (0.319) and  $r_s$  (0.452); awareness of CCH inform the willingness to reduce BEU reveals the C's value (0.322) and  $r_s$  (0.449); and awareness of carbon emissions informing the willingness to reduce BCF indicate C's value (0.312) and  $r_s$  (0.426) indicated significant correlations.

A further series of Chi-Square tests were performed on the relationship between awareness of BEP and other study variables. Table 7:16, shows the result of Chi-Square tests on combined variables based on these questions:

- Does awareness on BEP inform the willingness to change to more energy efficient habit?
- Could awareness on BEP inform the willingness to reduce building energy consumption?
- Does awareness on CO<sub>2</sub> inform the willingness to reduce building carbon footprint?

Table 7:16: Cross Tab: Environmental Issues- Awareness and Willingness/ Concerns2.

Case processing summary							
	Chi-Square Tests						
	Likelihood Ratio; Cramer's V value ; Spearman r <sub>s</sub>						
	Valid N	expected count < 5	$\alpha$ -value	Value; P-value	Value; P-value	P-value; 2-tailed sign	df
BEEP *EE Habits:	139	64.0%	.050	67.156; .000	.379; .000	.448; .000 <sup>c</sup>	16
BEEP* reduce BEU:	138	64.0%	.050	53.124; .000	.329; .000	.404; .000 <sup>c</sup>	16
BEEP* reduce Carbon footprint:	138	60.0%	.050	48.361; .000	.326; .000	.365; .000 <sup>c</sup>	16

All the results (Table 7:16,.) reveal significantly positive linear associations for the three tests. The relationship between awareness of BEP and: the willingness to change to more EE habit indicates: C's value (0.379) and rs (0.448); the willingness to BEU indicates: C's value (0.329) and rs (0.404); and the willingness to reduce BCF displays: C's value (0.326) and (rs = 0.365) at the 5% level of significance.

#### 7.2.11 Awareness on BEE & Environmental Norms as EE Driver.

User's energy behaviour and awareness are amongst the focussed issues in the current study. Hence, the phenomenon of occupant's awareness on BEE and environmental issues for driving BEU and carbon emissions reduction is investigated. The preposition that a better-informed occupant will most likely imbibe EE habits/ attitude and use less energy is explored herewith. Participants' perception (N= 166), is obtained and measured using the 5-point Likert's scale (1 = strongly disagreed to 5 = strongly agreed).

The result indicates greater percent of occupants in the UK (83.8%) agreed that occupant's awareness will drive BEU and CO<sub>2</sub> emissions reduction than those in Nigeria (79.1%). Whilst those that were neutral in Nigeria (16.4%), are more than those in the UK (12.5%). The UK's respondents formed greater percent of those who agreed and strongly on study variable than their Nigeria counterparts.

The distribution curves for both countries are normal but different in pattern. The result shows that both countries have the same median, range and modal value (4.00). However, there is a difference in their SM and SD: UK (4.14; 0.83; n= 80) and NG (3.91; 0.77; n= 67) respectively, confirming greater agreement on the variable in the UK than Nigeria. The general result also

has SM (4.04) with SD < 1.00 (0.80); negative skewedness (-0.98) and a positive kurtosis (1.98). The result exhibited strong agreement on occupant's awareness on BEE and environmental issues drives BEU and CO<sub>2</sub> emissions reduction.

#### 7.2.12 Perceived Barriers to BEP

The study identified barriers and drivers for building energy use efficiency. Hence, respondents (N= 166; n= 130), were asked to rank their agreement or disagreement to these perceived barriers based on 5-point Likert's scale. The data were analysed based on the aggregate of a greed (valid percent) frequency; relative index analysis; and a ranking of variables.

The Nigeria result (Table 7:17), indicates behaviour & lifestyle (76.6%; RIA = 1<sup>st</sup>), is perceived as the most critical barriers to BEU efficiency. Likewise, other variables are ranked in the same comparison as follows: incomplete / imperfect information on EE (65.6%; RIA = 2<sup>nd</sup>); lack of building energy codes and standards (51.4%; RIA = 3<sup>rd</sup>); and lack of regulatory policy and institutional framework (50.0%; RIA = 4<sup>th</sup>). Other perceived barriers, but lower in the critical hierarchy are: poor energy supply chain (37.5%; RIA = 5<sup>th</sup>); lack of technical skill (34.3%; RIA = 6<sup>th</sup>); and sharp practices (32.9%; RIA = 7<sup>th</sup>).

Table 7:17: Perceived Barriers to BEU Efficiency.

Perceived Barriers to BEU Efficiency: NIG	Valid N	Ranking of Perceived Barriers to BEU Efficiency: Based on Likert's scale: 1= Strongly disagreed; 2= Disagreed; 3= Neutral; 4= Agreed; & 5= Strongly agreed.					Agg. Frequency: Concerned Valid %	Ranking: Freq. Agg. Concerned	Relative Index Analysis	RIA Ranking
		1	2	3	4	5				
Answer Options	n									
Lack of regulatory policy and institutional framework	64	1	4	27	24	8	50.0	4	410	4
Lack of building energy codes and standards	64	1	4	26	26	7	51.4	3	422	3
Incomplete / imperfect information on energy efficiency	64	0	2	20	32	10	65.6	2	538	2
Behaviour & Lifestyle	64	0	1	14	32	17	76.6	1	627	1
Poor energy supply chain	64	1	5	34	18	6	37.5	5	307	5
Sharp practices	64	0	6	37	17	4	32.9	7	269	7
Lack of technical skill	64	0	6	36	15	7	34.3	6	282	6

Result for the Nigeria participants however, varied significantly for the result of the UK's. A majority, of the occupants in Nigeria were neutral on the issues of poor energy supply chain (53.1%), sharp practices (57.8%), and lack of technical skill (56.3%). The respondents were unsure of these factors being perceived as hindrances to BEU efficiency due to either: they are not willing to expose the weakness of their organisations; or they are guilty of such offence

(sharp practices); or they are contributors to such offences; and / or they could not see the linkage between these variables and BEE for lack of awareness.

A similar analysis was carried out on the response data for UK's occupants (Table 7:18). The result displays the slight deviation from that of Nigeria. Unlike the previous results, lack of regulatory policy and institutional framework (84.0%; RIA ranking = 1<sup>st</sup>), is perceived as the most critical barriers to BEE. Whilst, lack of building energy codes and standards (81.1%; RIA = 2<sup>nd</sup>), is the next critical barrier. Behaviour & lifestyle (78.4%; RIA = 3<sup>rd</sup>), is chosen as the third most significant barrier. Whereas incomplete / imperfect information on energy efficiency (77.4%; RIA = 4<sup>th</sup>) is perceived as the fourth most critical barrier.

Table 7:18: Perceived Barriers to BEU Efficiency.

Perceived Barriers to BEU Efficiency: UK	Valid N	Ranking of Perceived Barriers to BEU Efficiency: Based on Likert's scale: 1= Strongly disagreed; 2= Disagreed; 3= Neutral; 4= Agreed; & 5= Strongly agreed.					Agg. Frequency: Concerned	Ranking: Freq. Agg. Concerned	Relative Index Analysis	RIA Ranking
		1	2	3	4	5				
Answer Options	n						Valid %			
Lack of regulatory policy and institutional framework	75	1	4	7	36	27	84.0	1	945	1
Lack of building energy codes and standards	74	1	6	7	39	21	81.1	2	888	2
Incomplete / imperfect information on energy efficiency	75	0	4	13	41	17	77.4	4	870	3
Behaviour & Lifestyle	74	1	3	12	39	19	78.4	3	858	4
Poor energy supply chain	74	1	8	10	32	23	74.3	6	814	6
Sharp practices	75	1	5	19	32	18	66.7	7	750	7
Lack of technical skill	73	1	6	10	31	25	76.7	5	818	5

Other factors that are perceived as critical barriers are: Lack of technical skill (76.7%; n = 73; Agg. Freq. & RIA ranking = 5<sup>th</sup>); Poor energy supply chain (74.3%; n = 74; Agg. Freq. & RIA ranking = 6<sup>th</sup>); and Sharp practices (66.7%; n = 75; Agg. Freq. & RIA ranking = 7<sup>th</sup>).

### 7.2.13 Perceived Drivers to BEE

Result (Table 7:19), for Nigeria reveal that majority of respondents perceived renewable energy technology as the most critical drivers BEE. Renewable energy (78.2%; RIA= 1<sup>st</sup>), ranked top amongst other perceived drivers. It was closely followed by SEM (75.0%; n = 64; ranking = 2<sup>nd</sup>); energy PMs, & KPIs (73.4%; RIA = 3<sup>rd</sup>); and BEMS (70.3%; RIA = 4<sup>th</sup>), respectively. Although, others: behavioural change tool (67.2%; RIA = 5<sup>th</sup>); ESP/ SFM (63.5%; RIA = 6<sup>th</sup>);

and transparent & ethical business practices (60.3%; RIA = 7<sup>th</sup>), are strongly perceived as drivers, they are nonetheless, lower in ranking as indicated.

Table 7:19: Perceived Drivers to BEE- NG.

Perceived Drivers to BEU Efficiency: NIG	Valid N	Ranking of Perceived Drivers to BEE: Based on Likert's scale: 1= Strongly disagreed; 2= Disagreed; 3= Neutral; 4= Agreed; & 5= Strongly agreed.					Agg. Frequency: Concerned	Ranking: Freq. Agg. Concerned	Relative Index Analysis	RIA Ranking
Answer Options	n	1	2	3	4	5	Valid %			
*Embedded Sustainability Policy & strategic Facilities Management	64	0	1	16	38	9	63.5	6	602	4
*transparent & ethical business practices	63	0	0	25	29	9	60.3	7	479	7
*Behavioural change tool	64	0	0	21	29	14	67.2	5	550	6
*Energy performance metrics & indicators for assessment / benchmark	64	0	1	16	34	13	73.4	3	602	4
*Renewable energy technology option	64	0	0	14	38	12	78.2	1	640	2
*Strategic Energy management	64	0	0	16	38	10	75.0	2	614	3
*Building Energy Management Technologies	63	0	0	19	31	41	70.3	4	907	1

The UK's data result similarly indicates same pattern with the general result but in slight variance with the Nigeria result. It also confirmed all study variables as strongly perceived drivers for BEE (Table 7:20).

Majority of the respondents in the UK, opined that SEM (90.7%; RIA = 1<sup>st</sup>), is the most critical driver amongst these variables. Whilst BEMS (88.0%; RIA = 2<sup>nd</sup>); transparent & ethical business practices (87.0%; RIA = 3<sup>rd</sup>); and PMs. & KPIs (85.0%; RIA = 4<sup>th</sup>), also received high perceived ranking as drivers. Other accepted drivers, but lower in ranking are: renewable energy technology (83.1%; RIA = 5<sup>th</sup>); ESP/SFM (82.9%; RIA = 6<sup>th</sup>); and behavioural change tool (80.0%; RIA = 7<sup>th</sup>).

Table 7:20: Perceived Drivers to BEE- UK.

Perceived Drivers to BEU Efficiency: UK	Valid N	Ranking of Perceived Drivers to BEE: Based on Likert's scale: 1= Strongly disagreed; 2= Disagreed; 3= Neutral; 4= Agreed; & 5= Strongly agreed.					Agg. Frequency: Concerned	Ranking: Freq. Agg. Concerned	Relative Index Analysis	RIA Ranking
Answer Options	n	1	2	3	4	5	Valid %			
*Embedded Sustainability Policy & strategic Facilities Management	76	0	0	13	39	24	82.9	6	958	5
*transparent & ethical business practices	77	0	1	9	42	25	87.0	3	1032	1
*Behavioural change tool	75	0	2	13	41	19	80.0	7	900	7
*Energy performance metrics & indicators for assessment / benchmark	76	0	1	10	41	24	85.0	4	988	4
*Renewable energy technology option	74	0	0	11	39	24	83.1	5	932	6
*Strategic Energy management	75	0	1	6	45	23	90.7	1	1020	2
*Building Energy Management Technologies	75	1	1	7	38	28	88.0	2	990	3

Results for both countries of the preference and ranking of perceived drivers for BEP, revealed a disparity in view of respondents. Though all variables were accepted as critical driving factors, the relevance and impacts of each factor differ between both countries. In the UK for instance, SEM, BEMS, transparent & ethical business practices, and PMs, & KPIs are considered the most preferred best practice solutions for improving BEP. Whereas, in Nigeria, priority is given to renewable energy technology, SEM, PMs-&-KPIs, and BEMS as best practices in order of decreasing preference.

#### 7.2.14 Non-Parametric Test: Barriers and Drivers for BEP

The study likewise seeks to know the following: how could a barrier factor cause or lead to another barrier; how could a propelling factor (driver) cause another variable to propel building energy efficiency (BEE); and the reason for each relationship. The possible reasons why each relationship exists, could only be explored through further test. Hence, the use of Chi-Square statistics as follows:

##### *I. Barriers to BEP*

The following propositions were used in studying the barrier's variables:

- The lack of building energy codes and standards (ECS) does not inform sharp practices; and the lack of technical skill for regulating/ reducing building energy use
- Incomplete / imperfect information on BEE does not inform wrong behaviour & lifestyle?

The results Table 7:21, generally reveals strong positive linear with each paired variable.

Table 7:21: Pairs of Barrier to BEE.

Cross Tab: Pairs of Barriers to BEE: Case processing summary							
r <sub>s</sub>	Chi-Square Tests						
	Likelihood Ratio; Cramer's V value ; Spearman						
	Valid N	expected count < 5	$\alpha$ -value	Value; P-value	Value; P-value	P-value; 2-tailed sign	df
Reg. framework							
*Sharp Practices: Building ECS	137	64.0%	.050	69.091; .000	.424; .000	.465; .000 <sup>c</sup>	16
*Sharp Practices: Building ECS	136	68.0%	.050	51.928; .000	.362; .000	.472; .000 <sup>c</sup>	16
*Technical skills : Building ECS	133	60.0%	.050	70.410; .000	.398; .000	.549; .000 <sup>c</sup>	16
*Behav.& Lifestyle: Incomp. Inform.*	135	60.0%	.050	47.331; .000	.322; .000	.444; .000 <sup>c</sup>	16
Behav. &Lifestyles: Incomp. Inform.*	136	55.0%	.050	73.314; .000	.495; .000	.582; .000 <sup>c</sup>	12
Technical skills :	136	50.0%	.050	74.955; .000	.475; .000	.572; .000 <sup>c</sup>	12

Results (Table 7:21) of tests on lack of: regulatory policy/ institutional framework & incidence of sharp practices; building energy codes/ standards & incidence of sharp practice; and building energy codes/ standards & lack of technical skill indicates significantly strong and positive correlations between paired variables. Hence, rejection of the null hypothesis and acceptance of the alternative.

The result (Table 7:21) of tests performed on: lack of building energy codes/ standards and its relation with users' behaviour & lifestyle; correlation between incomplete/ imperfect information and with users' behaviour & lifestyle; and the incomplete/ imperfect information and technical likewise, indicate significantly strong and positive correlations between paired variables. Hence, rejection of the null hypothesis and acceptance of the alternative.

## II. Drivers to BEP

The current study also seeks to understand the associations between study driver's predictor variables. The following null hypotheses are proposed for testing:

- Embedded Sustainability policy (ESP) & strategic facilities management (SFM) does not have correlation with strategic energy management (SEM) in driving BEP?
- ESP & SFM have no correlation with BEMS in driving BEP?
- ESP & SFM do not have a relationship with transparent & ethical practice in driving BEP?
- ESP & SFM have no affiliation with assessment & benchmarking (PMs/KPIs) in driving BEP?
- Renewable energy technology does not influence SEM in driving BEU reduction?



- Behavioural change tool (BCT) does not influences transparent & ethical business (T&EB) practices in driving BEP?

Results for all tests (Table 7:22), revealed strong positive correlations for paired predictor variables on the drivers of BEP. The result based on Chi-Square likelihood test, Cramer's V, and Spearman's rho tests, indicates very significant associations and strong linear relations. Adeptly, the test results rejected all proposed null hypotheses as proposed above, and consequently accepted individual alternative proposition as follows:

Table 7:22: Pairs of Driver to BEE-2.

	Chi-Square Tests						
	Likelihood Ratio; Cramer's V value ; Spearman $r_s$						
	Valid N	expected count < 5	$\alpha$ -value	Value; P-value	Value; P-value	P-value; 2-tailed sign	df
ESP & SFM *SEM:	138	43.8%	.050	88.466; .000	.485; .000	.671; .000 <sup>c</sup>	9
ESP & SFM *BEMS :	137	43.8%	.050	94.087; .000	.508; .000	.670; .000 <sup>c</sup>	9
ESP & SFM *T& EBP:	138	43.8%	.050	99.234; .000	.515; .000	.681; .000 <sup>c</sup>	9
ESP/SFM *PMs/KPIs	139	43.8%	.050	92.134; .000	.502; .000	.634; .000 <sup>c</sup>	9
ESP & SFM *Renew.:	137	43.8%	.050	73.813; .000	.556; .000	.615; .000 <sup>c</sup>	6
Behav. tool* T&BP:	138	43.8%	.050	99.234; .000	.515; .000	.681; .000 <sup>c</sup>	16

The results (Table 7:22), for all the tests on relationship between: ESP/SFM and SEM; ESP/SFM and BEMS; ESP/SFM with T& EBP; ESP & SFM with PMs/KPIs; ESP & SFM with renewable technology options; and BCT with T&EB practices, all equally indicated significantly positive and extremely strong relationship. Hence, they are associated.

#### 7.2.15 Discussion

Quest-surv1 findings suggest that comfort perception is a vital element that affect building energy performance (Ole Fanger, 2001). Bldg101 and Bldg206 were rated as the most comfortable in both seasons under the two groups. The plausible reason is that much of the energy used for comfort in Bldg101 is based on fossil-fuel generators that constantly power the building. Whilst, the use of constant mechanical ventilation in Bldg206 irrespective of the season with temperature set at  $20^0\text{C}\pm 1$ , also accounts for high based loads (50%) as indicated in Bldg206 EPL result.

The study confirmed the importance of installed BEMTechs such as: building energy management systems (BEMS), data acquisition system (DAS), temperature and humidity control (THC), access lock control, and lighting Sensors etc. for reducing existing stock BEU. Past studies (Ma et al., 2012; Agha-Hosseini et al., 2013), have confirmed that technological intervention has resulted to about 60.0% energy savings in existing buildings.

Occupant energy-use behaviour and lifestyle were highlighted in both countries (Li, Hong and Yan, 2014b). Findings indicate that Nigeria case building users has the strongest PBC on shading (64.7%) lighting (57.8%), and cooling (55.9%). Whilst those in the UK case buildings have PBC on shading (81.7%), lighting (72.8%) and ventilation (65.8%), but with lesser control of heating (42.7%).

Findings on users' energy habit indicates that the occupants in Nigeria (63.6%), have a higher BEE habit than those in the UK (45.0%). This could be ascribed to the use of technologies (lighting sensors) in the UK case buildings. Whereas, Nigeria case buildings lacked these efficient lighting systems, thus occupants' attitude seem to be developing attitude towards the habit of 'switching-off often'. The habit was also linked to increasing awareness of environmental values, energy crisis and increasing electricity cost in Nigeria.

Awareness and concerns for environmental values (norms) was found to be critical for reducing BEU and improvement of BEP. Previous study (Altan, 2010), had shown that awareness (staff and Students), had helped in about 7-18% savings on BEU with a success rate of 70-77% success record. However, the issues of buildings' carbon emissions, carbon footprint and its EEP were ambiguous to participants. Hence, the level of awareness on the impact of climate change risks on buildings, adaptation and mitigation is still relatively low amongst users in both countries especially in Nigeria.

Incomplete and imperfect information on BEE was ranked high amongst the barriers to BEP in the study. This corroborates the IPCC report (Victor et al., 2014), which cited imperfect information as amongst the barriers that hinder the uptake of cost-effective opportunities for reducing building emissions. While, occupant behaviour is another critical factor found to be affecting BEP. The study confirmed that BCT is a useful tool for driving BEU reduction and BEP. A recent study (Dubois et al., 2015), also confirmed the usefulness of behavioural change by highlighting its advantages.

The current study shows that SEM Policy is a strong driver for BEP. Findings confirmed that the deployment of strategic energy policy issues: energy performance goals, EEP, and formulation and implementation of energy performance goals, aid effective management and operational solutions to reducing BEU (Rudberg, Waldemarsson and Lidestam, 2013)

Just as corruption was considered by respondents as critical barriers to BEP in Nigeria (Frynas and Mellahi, 2003). The finding demonstrated that greater corruptibility of policy makers reduces the stringency of EE policy (Fredriksson, Vollebergh and Dijkgraaf, 2004). While the result reveals that poor supply chain was considered by participants as effective barriers (RIA= 6<sup>th</sup>) to BEP (Tallapragada, 2009). This is also associated with severe labour and social unrests (Nworu, 2016), underpinned by corruption and politics.

#### 7.2.16 Summary

The study investigated the factors that affect BEP of the ten case buildings in Nigeria and the UK via the use of a POE survey. It was discovered that identified installed building technologies are perceived to improve BEP. However, it was found that BEMS and DAS installations are not a common occurrence in the Nigeria context. The perceived comfort of the case buildings was investigated. The result indicated that case bldg101 and bldg210 were considered the most comfortable. Generally, study case buildings (in Nigeria and UK) are perceived more comfortable in the rainy (winter) season than in the dry (summer) season.

Occupants' energy behaviour was investigated, it was discovered that user's PBC, EE habits/ attitude, intentions are significant factors that influence BEU in both countries; hence BEP improvement. Also, participants in both countries agreed to the use of FM as a tool; maintenance and energy retrofits; and frequent energy assessment and benchmarking to improve BEP.

The current study also examined the relationship between environmental norms, awareness and concerns/willingness from occupants. The results indicate higher awareness on environmental norms: CCH, global warming, CO<sub>2</sub> emissions, BEP, SD, carbon footprint and EE by occupants in both countries. Awareness on CCH and global warming were the highest, whilst, awareness on BEP and carbon footprint were the lowest amongst participants (Nigeria and UK). Also

significantly strong associations were established between occupants' concerns/ willingness to change and environmental norms; and users' EE habits and these environment norms.

Finally, it established the factors serving as barriers and drivers to BEP improvement. It was discovered that the lack of regulatory policy, building codes and standards informed sharp practices and lack of skilled personnel. While incomplete /imperfect information informed users' energy use behaviour and lifestyle. Particularly, the associations between combined ESP/SFM and: SEM; BCT; PMs; KPIs; BEMS; renewable technologies, were found to be strongly correlated and influences BEP improvement.

### 7.3 PROFESSIONAL VIEWS BASED ON QUEST-SURV2

#### 7.3.1 Descriptive Analysis

Quest-surv2 was used to obtain opinions of FMs, estate managers and operators on technical and operational issues from within and outside case buildings. It became necessary as most of the participants of 1<sup>st</sup> POE are non-professionals. They might not comprehend sound technical issues that affect BEU and EEP; and whose opinion could be confined within case buildings. The study is specifically used in investigating technical, managerial and operational contexts based on professional judgement. While the RIA was used for comparing response data.

#### 7.3.2 Demographics

The participants for Quest-surv2 were mainly professional FMs in Nigeria and the UK. Participants were drawn from organisations within case buildings, and members of a Nigeria chapter of International Facilities Management Association (IFMAN). They comprised independent practitioners (consultants), and in-house facilities/ maintenance managers in organisations within case study buildings. Respondents (N= 48), were asked to indicate their gender, location, education, and FM organisation category.

The result reveals that most of the respondents are male (83%), while 83.0% of respondents (n = 39) lived in Nigeria, and 17.0% (n = 8) reside in the UK. Also, the study investigated respondents' professional and educational qualifications to ensure that only the learned in the

subject matter are sampled. The result (Figure 7.8), reveals that almost all the participants (93.3%) are educated up to first degree level.

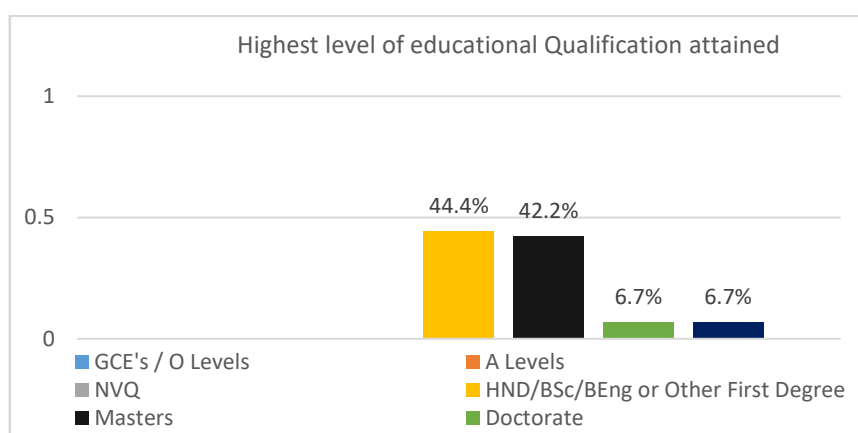


Figure 7.8: Level of Educational Qualification

A 19.0% of participants in Nigeria, belong to the International Facilities Management Association whilst, others belong to other professional institutions. 11.9% are members of Royal Institution of Chartered Surveyors (RICS) in the UK. Another 9.5% (the respondents) were members of the British Institute of Facilities Managers (BIFM); and similarly, others belong to other professional institutions.

Result indicates representation from all FM sectors. About two third of them (about 61.9%;  $n = 26$ ) worked in various organisations' in-house FM/ maintenance department. Also, less than a third of them worked in independent consultancy firms (16.7%;  $n = 7$ ), and FM service provider firms (9.5%;  $n = 4$ ). While less than a quarter of the participants (11.9%;  $n = 5$ ) worked in other non-FM companies.

Respondents' firms do businesses in various sectors of both countries. 35.6% of the organisation are found in the education sector. Another 26.7% worked in the construction & allied services. While 11.1% each belongs to the government & public corporations; and the banking & finance sectors. Others FM firms are found in other sectors. Furthermore, the Cronbach's alpha test for Quest-surv2 result indicated alpha by 0.907 and 0.941 on standardized items ( $N = 110$ ).

### 7.3.3 FM Functions (Roles) in the Organisation

The study investigated the functions of facilities managers in the organisation. Respondents are asked to indicate their level of involvement in six areas of strategic building management (SBM) derived from previous studies.

The identified areas are: managing the physical fabric of existing/ new buildings (MPFB); managing the equipment and furniture within facilities (MEFF); facility's energy management (FEM); facility's waste management (FWM); facility's routine & emergency repairs, planned maintenance, and refurbishment (FRERPMR); and monitor and measure all sustainable policy metrics achieve targeted sustainable goals (MMSP).

*Table 7:23: FM Roles in Organisation.*

FM Roles in the Organisation	Valid N	F. Manager involvement: Likert's Scale (1= very weak; 2= weak; 3= Neutral; 4= Strong; & 5= Very strong): NIG.					Agg. Agreed frequency	Agreed Freq. Ranking	Relative Index Analysis	RIA Ranking
		1	2	3	4	5				
MPFB	42	0	3	3	15	21	85.7	4	302	2
MEFF	38	0	3	2	13	20	86.8	3	251	4
FEM	40	0	2	2	15	21	90	1	288	3
FWM	37	1	1	2	18	15	89	2	244	5
FRERPMR	40	0	2	0	14	24	85	5	304	1
MMSP	37	0	1	5	12	19	83.8	6	229	6

The result (Table 7:23), reveals that 80% of the respondents agreed with FM involvement in all the functions. About 90% of the participants (n= 35) believe that facilities managers are involved in all the identified areas. Based on RIA ranking amongst study variables, FRERPMR (RIA= 1<sup>st</sup>), and MPFB (RIA= 2<sup>nd</sup>) received the strongest rating. Others: FEM, MEFF, FWM and MMSP are also seen as FM roles in the organisation.

### 7.3.4 Organisations with Sustainability Policy (SP) and Executive Actions

The study obtained a professional's view (valid n = 37) on SP, and executive actions on organisation's building energy bills and operational cost. The result (Table 7:24), based on the Likert's 5-point scale, showed that 90% of the respondents opined that SP is a propelling tool for enhancing facility energy performance. SP (1<sup>st</sup>) and organisation's action towards building energy bills reduction (2<sup>nd</sup>), were ranked highest amongst construct's variables.

Table 7:24: Sustainability Policy and Executive Action.

Organisation with Sustainability Policy (SP) and Executive Actions	Valid N	FM with (SP) and Executive Actions Rating: Likert's Scale (1= strongly disagreed; 2= disagreed; 3= Neutral; 4= agreed; & 5= strongly agreed)					Agg. Agreed frequency	Agreed Freq. Ranking	Relative Index Analysis	RIA Ranking
		1	2	3	4	5				
Options	n						Valid %			
Sustainability Policy enhances Facilities energy performance	41	0	1	4	16	20	87.8	1	295	1
My organisation has written sustainable policy (SP)	41	2	5	9	14	11	60.9	4	205	4
My organisation has no SP	38	14	9	7	7	1	21.0	5	61	5
My organisation take steps to reduce energy bills	41	2	2	2	21	14	85.3	2	287	2
BEU cost is the most significant in operational lifecycle cost.	41	1	1	7	17	15	78.4	3	262	3

The professionals also agreed that BEU cost (3<sup>rd</sup>), is the most significant cost element in the operational lifecycle of buildings. Likewise, SP is fully established in some of the FMs' organisations.

### 7.3.5 FM Functions as Influencing Factors on BEE

The participants (valid n = 36) were asked to rank the FM functions as factors influencing BEE based on the Likert's 5-point scale, and were ranked based on RIA as thus:

- Planning and ensuring efficient supply of resources (Planning & Resource Supply)
- Influencing the behaviour of individual working within the building facility they manage (Influencing User's Behaviour)
- Develop and implement programmes to reduce energy consumption of the facility (Energy Reduction programmes)
- Adopting energy efficiency measures like switching to efficient lighting equipment (Efficient switching: Lighting & equipment)
- Review and monitoring the total facility energy used (Energy Audit)
- Matching heating & cooling & Ventilation equipment to facility loads to reduce energy consumption (HVAC matching)
- Develop and implement energy retrofit programme (Retrofit Programme)
- Identify energy performance indicators for monitoring progress (Identify KPIs)
- Monitoring and evaluating carbon footprint, including responsibility for target, measurement and reporting (Monitoring & evaluation of the CFP)

The result (Figure 7.9), shows that almost 100% of the professionals accepted all study variables as factors influencing BEE. Amongst the listed functions, energy reduction programmes (100.0%;  $\mu = 4.50$ ; RIA = 1<sup>st</sup>); and efficient switching: lighting & equipment (98.3%;  $\mu = 4.47$ ; RIA = 1<sup>st</sup>), are adjudged the most critical factors influencing BEE.

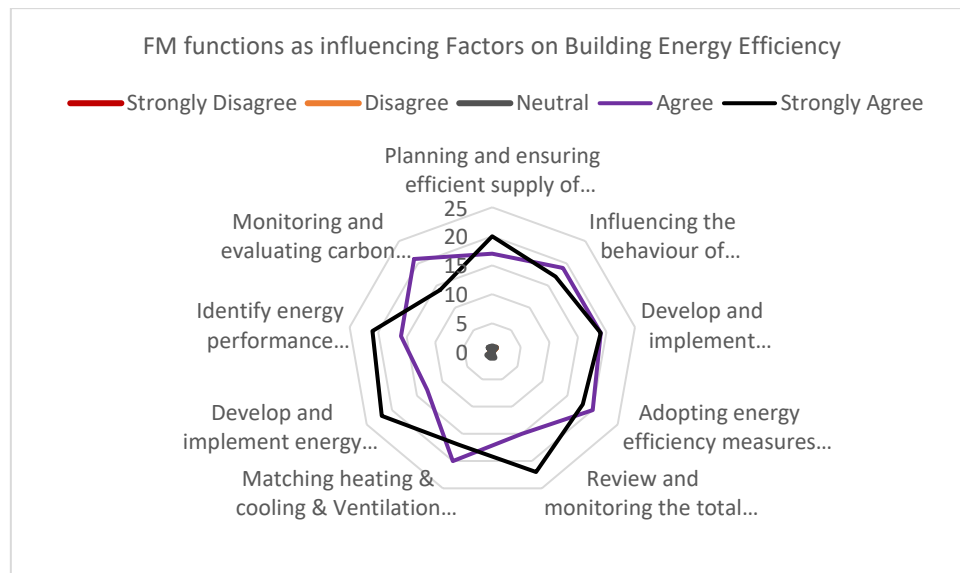


Figure 7.9: FM Functions influencing BEE.

Other FM functions and perceived strengths are: planning & resource supply (97.3%;  $\mu = 4.50$ ; RIA = 3<sup>rd</sup>); energy audit (97.4%;  $\mu = 4.55$ ; RIA = 3<sup>rd</sup>); and HVAC matching (97.3%;  $\mu = 4.42$ ; RIA = 3<sup>rd</sup>). Whilst, identified KPIs (100.0%;  $\mu = 4.57$ ; RIA = 6<sup>th</sup>); influencing user's behaviour (94.7%;  $\mu = 4.37$ ; RIA = 7<sup>st</sup>); retrofit programme (94.6%;  $\mu = 4.51$ ; RIA = 8<sup>st</sup>); monitoring & evaluation of CFP (97.2%;  $\mu = 4.36$ ; RIA = 8<sup>th</sup>), are perceived as potentials for driving BEE.

### 7.3.6 Effective Barriers to BEE

Professional perspective on the barriers to building energy efficiency (BEE), is obtained via 5-point Likert scale; and ranked based on RIA. The result (Figure 7.10), indicates the acceptance of all study variables as critical barriers to BEE by more than two-third of the participants.



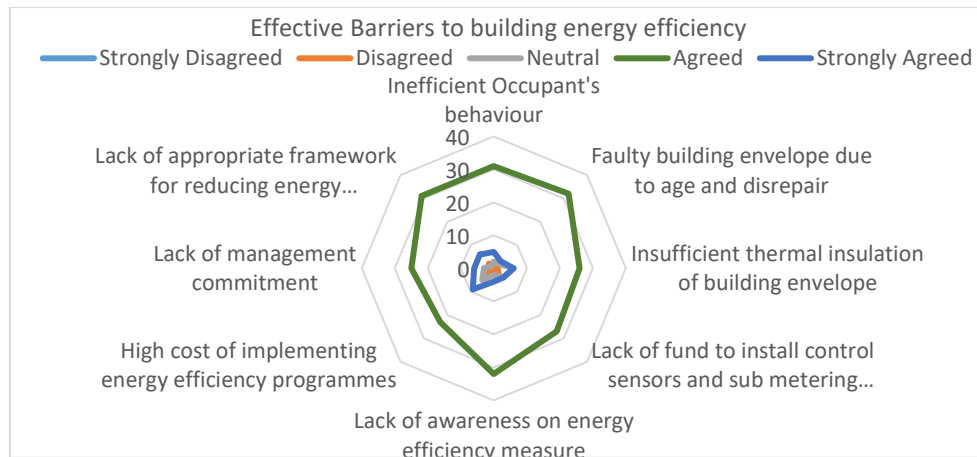


Figure 7.10: Effective Barriers to BEE

About 90% of the respondents perceived: lack of framework for reducing energy expenditure (1st); lack of awareness of energy efficiency measure (2nd); inefficient occupant behaviour (2nd); and faulty envelop (4th), as the most critical barriers. Whilst, about 70% of professionals also perceived: high cost of implementing energy efficiency measure (5<sup>th</sup>); insufficient thermal envelop insulation (6<sup>th</sup>); lack of finance for installation of BEMS; and lack of management commitment as critical barriers.

### 7.3.7 Perceived Barriers to FM Practices & Impacts on EEP

FM is a new evolving practice in Nigeria, hence the study investigated the factors that serve as its barriers. The opinion of FMs (n= 41), were obtained through the 5point Likert's scale based on listed variables derived from previous studies. Result (Table 7:25), reveals that more than 70% of participants agreed that all study variable on the construct are critical barriers to the practices of FM. Hence, they impact on BEP.

Table 7:25: Perceived Barriers to FM Practice.

Effective Barriers to BEE	Valid N	Effective Barriers to BEE Rating: Likert's Scale (1= Strongly disagreed; 2= disagreed; 3= Neutral; 4= agreed; & 5= Strongly agreed):					Agg. Agreed frequency	Valid %	Agreed Freq. Ranking	Relative Index Analysis	RIA Ranking
		1	2	3	4	5					
Lack of training	42	1	3	5	22	11	78.6	4	277	4	
Lack of appropriate tools	42	1	3	3	23	12	83.4	1	294	1	
Lack of awareness on the responsibilities of FM	42	1	2	4	23	12	83.4	1	294	1	
Lack of appropriate strategic energy efficiency policy by organisation	41	1	3	7	21	9	73.2	5	246	5	
Lack of knowledge of energy efficiency measures by FM practitioners	41	2	3	7	18	11	70.7	6	238	6	
Lack of senior management commitment	42	2	1	5	17	17	81.0	3	286	3	

More than 80% of the FMs agreed strongly that: lack of appropriate tool (1<sup>st</sup>); lack of awareness of the responsibility of FM (1<sup>st</sup>); and the lack of management commitment (3<sup>rd</sup>), are strong barriers to FM practices and could hinder BEE. Whilst, > 70% of the participants opined that: lack of training (4<sup>th</sup>); lack of energy efficiency policy in the organisation (5<sup>th</sup>); and lack of knowledge of EE measures by professional FMs (6<sup>th</sup>), are certainly strong barriers to FM practices that impact on BEE.

### 7.3.8 Factors Influencing BEU

The respondents (n= 34), were asked to rate the factors influencing BEU. The 7-point Likert' scale was used for measuring the construct based on: 1 being certainly unsure (-1) to 7 being certainly sure (+3). The variables were further ranked based on RIA. The result (Table 7:26), shows that all variables are strongly perceived as factors influencing BEU. The participants responded with minimum  $\mu = 5.53$  and maximum  $\mu = 6.19$  for all measured variables.

Table 7:26: FM's ranking of Factors influencing BEU.

FM's Perception on factors influencing BEU	Valid N	FM's Perception on factors influencing building energy use: Likert's Scale (1= certainly unsure [-1] to 7= certainly sure [+3]):							Relative Index Analysis	RIA Ranking
		1	2	3	4	5	6	7		
Climate	38	2	1	3	4	4	7	17	298	5
Building Envelope	36	1	0	1	4	6	11	13	247	7
Building Electrical/ Mechanical Equip	38	0	1	2	1	4	11	19	353	1
Operation & Maintenance	37	0	0	2	0	5	12	18	336	2
Occupant's Behaviour	37	1	0	1	1	7	11	16	301	4
Indoor Environment Condition	38	1	1	2	3	6	12	13	259	6
Building Size	38	0	1	2	2	8	7	18	325	3

Building services (HVAC) (1<sup>st</sup>); and operation and maintenance (2<sup>nd</sup>), are perceived as the two most critical factors influencing BEU. Too, building size (3<sup>rd</sup>); occupant behaviour (4<sup>th</sup>); and climate (5<sup>th</sup>), are equally seen as critical factors that influences BEU based on their RIA. Whilst, indoor environmental condition (6<sup>th</sup>); and building envelope (7<sup>th</sup>), ranked lower in RIA, but were also seen as critical factors.

### 7.3.9 Effectiveness of Perceived Technical Solutions for EE

Some studies have proffered several technical solutions for BEU and efficiency performance. Hence, this study seeks to understand the effectiveness of these solutions through the

perception of FMs. The respondents were asked to rate the factors influencing BEU. The weighted 7-point Likert' scale and ranking based on relative strength index analysis (RSIA), were used for measuring the construct.

Data analysis result (Table 7:27), shows that all variables are strongly perceived as effective solutions for reducing BEU, hence improving BEP. The participants responded with minimum  $\mu = 5.41$  and maximum  $\mu = 6.32$  for measured variables.

*Table 7:27: Effectiveness Technical Solutions for Energy Use Reduction*

Effectiveness for purpose of Perceived Technical solutions used for reducing facility's Energy Use	Valid N	Effectiveness of Technical solutions used for reducing building energy use: Likert's Scale (1= very ineffective[-1] to 7= very effective [+3]):							Relative Index Analysis	RIA Ranking
		1	2	3	4	5	6	7		
Usage of energy consumption framework by management	34	0	0	4	4	6	8	12	209	5
Regular energy audit for facility	34	1	0	1	2	7	14	9	190	6
Regular assessment and Benchmarking (monitor, measure, review, & rate)	34	1	0	1	1	6	13	12	229	3
Installation of BEMS & DAS	33	1	1	1	2	4	12	12	216	4
Installation of PV solar panel	32	2	1	1	1	9	9	9	159	7
Matching HVAC equipment to Facility loads	34	0	0	2	2	8	9	13	231	2
Switching to more efficient lighting & equipment	34	0	0	1	1	3	10	19	319	1

Efficient lighting and equipment switching ( $\mu = 5.59$ ; 1<sup>st</sup>); HVAC matching ( $\mu = 5.17$ ; 2<sup>nd</sup>); and regular assessment and benchmarking ( $\mu = 5.88$ ; 3<sup>rd</sup>), are considered the most effective critical solutions for reducing BEU. Also, installation of BEMS & DAS ( $\mu = 5.78$ ; 4<sup>th</sup>); and management use of framework ( $\mu = 5.41$ ; 5<sup>th</sup>), are considered effective but with lesser relativity strength. Whilst, regular energy audit ( $\mu = 5.85$ ; 6<sup>th</sup>), and installation of solar PV panels ( $\mu = 6.32$ ; 7<sup>th</sup>), are considered less effective.

#### 7.3.10 Effectiveness of Managerial and Operational Solutions for BEE

Perceived effectiveness of several managerial and operational solutions for BEU and BEP was obtained. The weighted 7-point Likert' scale and ranking based on RSIA were used for measuring the construct. The result (Table 7:28), shows that all variables are strongly perceived as effective solutions for reducing BEU, hence BEP improvement. The participants responded with minimum  $\mu = 6.18$  and maximum  $\mu = 6.50$  for measured variables.

Table 7:28: Managerial & Operational Solutions for Reducing BEU.

Perceived Effectiveness of Managerial and Operational Solutions for Reducing Energy Consumption	Valid N	Effectiveness of Managerial and Operational Solutions for reducing building energy use: Likert's Scale (1= very ineffective[-1] to 7= very effective [+3]):							Relative Index x Analysis	RIA Ranking
		1	2	3	4	5	6	7		
Incorporation of sustainable policy in organisation's policies	34	0	0	1	1	9	7	16	269	2
Establishment of strategic energy performance/ efficiency policies	34	0	0	0	3	6	12	13	243	5
Establishment of energy performance goals	34	0	0	0	2	8	13	11	220	6
Formulation & implementation of energy performance policies	34	0	0	0	2	7	10	15	266	2
Education & Training of Occupants on Efficient & use of BEMS / DAS	34	0	0	3	2	5	10	14	246	4
Frequent physical walk-through & inspection process	34	0	0	1	1	7	11	14	254	3
Frequent planned, routine and emergency maintenance, repairs and refurbishment	34	0	0	0	1	6	9	18	304	1

The FMs strongly perceived: regular maintenance and refurbishment ( $\mu = 6.50$ ; 1<sup>st</sup>); organisation's sustainable policy ( $\mu = 6.38$ ; 2<sup>nd</sup>); and energy performance policy ( $\mu = 6.30$ ; 2<sup>nd</sup>), as the most effective solutions. Similarly, they perceived regular physical walk-through and inspection (technical survey) ( $\mu = 6.32$ ; 3<sup>rd</sup>); and education and training ( $\mu = 6.18$ ; 4<sup>th</sup>), are strongly agreed to be effective. Whilst, strategic energy performance policies ( $\mu = 6.30$ ; 5<sup>th</sup>); and energy performance goals ( $\mu = 6.29$ ; 6<sup>th</sup>), were equally perceived effective but lower in relativity strength.

### 7.3.11 Perceived Strength of Energy Performance Metrics (PMs)

The study seeks to select set of PMs that could be used as standard for energy assessment of existing buildings in Nigeria. The respondents were asked to rank the effectiveness of each metric as standard of measurement for BEU based on the 7-point Likert' scale. The result (Table 7:29), indicates that electric energy use (1<sup>st</sup>); lighting energy use (2<sup>nd</sup>); and building energy use intensity (BEUI) (3<sup>rd</sup>), were the strongest in relative strength weighted index amongst study variables.

Table 7:29: Perceived Strength of PMs.

Perceived Strength of Energy Performance Metrics (PMs)	Valid N	Perceived Strength of Energy Performance Metrics (PMs): Likert's Scale (1= very weak[-1] to 7= very strong[+3]):							Relative Index Analysis	RIA Ranking
		1	2	3	4	5	6	7		
Building energy use intensity (kWh/m <sup>2</sup> /yr.)	34	0	3	0	6	4	11	10	188	3
Carbon Dioxide emission (kgCO <sub>2</sub> /m <sup>2</sup> /yr.)	32	4	2	2	5	5	7	7	111	10
Electric energy use (kWh/m <sup>2</sup> /yr.)	34	1	2	0	4	7	8	12	207	1
Heating energy use (therms./m <sup>2</sup> /yr.)	33	2	5	0	5	5	6	10	154	5
Cooling energy use (kWh/m <sup>2</sup> /yr.)	34	1	3	1	2	8	9	10	180	4
Ventilation energy use (kWh/m <sup>2</sup> /yr.)	33	1	3	1	6	6	8	8	141	6
Lighting energy use (kWh/m <sup>2</sup> /yr.)	33	0	2	0	5	4	11	11	200	2
Net facility energy use (kWh/m <sup>2</sup> /yr.)	33	0	2	0	5	10	9	7	141	6
Plug loads energy use (kWh/m <sup>2</sup> /yr.)	32	0	2	0	7	8	8	7	132	8
People mover energy use (kWh/m <sup>2</sup> /yr.)	33	2	4	1	7	10	4	5	82	11
Domestic hot water energy use (kWh/m <sup>2</sup> /yr.)	32	3	3	1	3	8	7	7	116	9

Variables such as: cooling energy use (4<sup>th</sup>); heating energy use (5<sup>th</sup>); ventilation energy use (6<sup>th</sup>); net facility energy use (6<sup>th</sup>); and plug in loads energy use (8<sup>th</sup>), all received moderate relative index weight and ranking. Whilst, domestic hot water (DHW) energy use; carbon dioxide emissions; and people mover energy use were perceived as weak measure of the performance of building energy use.

### 7.3.12 Perceived Strength of Key Performance Indicators (KPIs)

The study also seeks to select set of KPIs that could be used as standard for benchmarking of existing BEP in Nigeria. The respondents (n= 27), ranked the effectiveness of each KPI as standard of benchmark for BEP. The weighted 7-point Likert' scale and ranking based on RSIA are used for measuring the construct. The result indicated (Table 7:30), reveals that all variables were ranked by the participants.

HVAC indicator (1<sup>st</sup>); EUI (2<sup>nd</sup>); and OP (3<sup>rd</sup>), got the highest weighting in descending order of relative strength. Amongst these three rated strong benchmarking metrics, HVAC indicator and BEUI were the most perceived strongest indicators for benchmarking BEP.

*Table 7:30: Perceived Strength of KPIs.*

Perceived Strength of Energy Performance Indicators (KPIs)	Valid N	Perceived Strength of Energy Performance Indicators (KPIs): Likert's Scale (1= very weak[-1] to 7= very strong[+3]):							Relative Index Analysis	RIA Ranking
		n	1	2	3	4	5	6		
Energy used intensity - EUI (kWh/m <sup>2</sup> /yr.)	32	0	1	1	3	7	8	12	201	2
Operational Rating- OP (kgCO <sub>2</sub> /kWh)	31	0	2	1	4	8	5	11	169	3
Comfort metric-CM (av. comfort index- 0-100)	30	0	2	3	5	6	7	7	117	10
Lighting Energy Use- LEUI (kWh/m <sup>2</sup> /yr.)	31	1	1	0	3	9	7	10	165	4
Energy Perform. Indicator (HVAC energy Use)	32	0	1	0	5	8	5	13	204	1
End-Use Energy Indicators- EUEI	30	1	1	2	3	6	6	11	164	5
Assert Rating Indicator- ARI	30	1	1	4	4	4	9	7	121	9
Occupant Stability indicator- OSI	31	0	2	3	5	5	7	9	146	7
U-value Performance indicator- U-Value PI	30	0	2	1	6	5	6	10	153	6
Air Permeability Indicator- API	31	0	2	1	5	8	7	8	137	8

Other indicators were perceived as standard measures for benchmarking, but with moderate strengths based on RSI. LEUI (4<sup>th</sup>); EUEI (5<sup>th</sup>); U-value PI (6<sup>th</sup>); and OSI (7<sup>th</sup>), are perceived to have lower strength in benchmarking BEP. Whilst, indicators such as: API; ARI; and Comfort metric are perceived to be weak for benchmarking BEP.

### 7.3.13 Benchmark Methods for BEP

FMs (n = 35), were asked to indicate the prefer choice of benchmarking method commonly used for BEP. The result (Figure 7.11), shows that 40% of the participants preferred the established benchmark method. Another 22.9% each, preferred its own past and performance of its peers. Whilst, 11.4% of the professionals preferred rate EER; and only about 2.9% opted for the established rule of thumb.

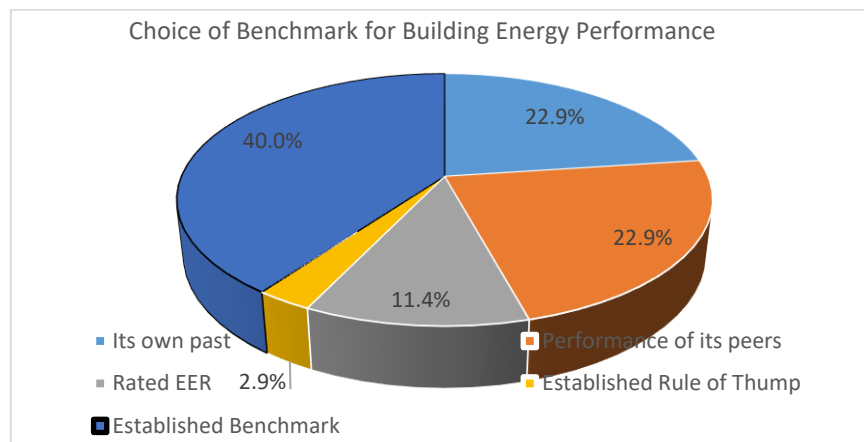


Figure 7.11: Choice of Benchmark Methods

### 7.3.14 Discussion

Quest-surv2 findings on SP and executive action established that SP enhances facility's energy performance. Past study (Elmualim, Valle and Kwawu, 2012), advocate for integration of sustainability into core business strategies in the organisation whilst, FM is considered a critical operational activity for improving BEP. Also, study result showed that respondents (70.0%) agreed that SFM and FM's roles are strongly associated with BEP model. A past study (Elmualim et al., 2010), named energy management, carbon footprint and FM handling of carbon emission reductions as amongst SP issues critical for managing facilities by FM.

The concept of SP and SFM are individually practiced daily within organisations, but the finding on adoption of policy integration, shows that embedded SP/SFM was considered as critical drivers for BEP in both Nigeria and the UK. It reinforced the position (Adewunmi, Omirin and Koleoso, 2012) that strategic management could be used in achieving sustainability in organisations.

Findings suggested regulatory policy as a critical factor to BEP. Result pointed to the lack of policy and institutional framework as amongst most critical barriers to BEE. The majority of participants in both countries (80%), considered it critical to BEP, which further confirmed a past study (Iwaro and Mwasha, 2010) finding.

Study findings indicate that building energy codes and standards (BECS) are necessary requirements for BEP. Most respondents (> than 70%), believed the lack of it is a strong barrier to BEE. Past study (Iwaro and Mwasha, 2010), confirmed that most African countries are still behind in building codes/ standard formulation, implementation and compliance compared to the developed countries. Also, energy standards have been proven to have significant impact on commercial BEU, and policy implementation has reduced building CO<sub>2</sub> emissions significantly (Scott et al., 2014).

Study findings also confirmed regular energy audit, assessment and benchmark, as one of the critical factors for reducing BEU and improving BEP (Ruparathna, Hewage and Sadiq, 2016). Across studies (quest-surv1 and 2), the factor is repeatedly identified as the critical driver for improving BEP.

Another factor that was confirmed to drive BEP improvement is standardised energy PMs/KPIs for assessment and benchmark (Deru and Torecellini, 2005). The study's professionals considered: electric energy use (RIA = 207; 1<sup>st</sup>); lighting energy use (2<sup>nd</sup>); and BEUI (3<sup>rd</sup>), as standard for the PMs Categories, and HVAC indicator (1<sup>st</sup>); BEUI (2<sup>nd</sup>); and OR (3<sup>rd</sup>) were considered as standardised KPIs.

Installation of low-zero carbon (renewable) technology options is widely adjudged as a critical factor that affect BEP across all studies. It was considered priority (RIA= 720; 1<sup>st</sup>) amongst other factors as for improving BEE. It supported a past study (Ibrahim et al., 2014) that resulted in 73.0-81.0% energy saving efficiency via installation of building integrated PV thermal systems.

Quest-surv2 findings also revealed that HVAC (RIA= 353; 1<sup>st</sup>) is a critical factor influencing BEU. Investment in HVAC system for school in Alberta, Canada, has helped to reduce district energy cost by 15% (Checkett-Hanks, 2010). Whilst, its findings also indicate that matching of HVAC equipment (RIA= 231; 2<sup>nd</sup>), is considered effective technical solution; and the most



critical functions of FM for improving BEP. Correct matching and operation of HVAC had saved about 30% energy used in commercial buildings (Fasiuddin and Budaiwi, 2011).

The study results confirmed finding in the quest-surv1, which that indicate the installation of efficient lighting and HVAC equipment as the most critical effective technical and operational solution (1<sup>st</sup>); and seen as one of the critical functions of FM for improving BEP. It corroborates the result of the past case study (Ardente et al., 2011), which had shown that high efficiency HVAC system had saved energy used in buildings. Another study (Stansbury and Mittelsdorf, 2001), found that efficient lighting system had saved up to annual energy cost savings; and saved about 53% as energy used reduction.

The findings likewise revealed built asset management issues (frequent, planned, routine and emergency maintenance; repairs and refurbishment including energy audit), as effective management and operational interventions. Nevertheless, these elements were perceived as the most principal functions of FM. Lighting retrofits of commercial buildings has achieved a 30.0-60.0% energy savings in past study (Bertoldi and Ciugudeanu, 2005).

Result for building envelope (RIA= 247; 7<sup>th</sup>), indicates that is a critical factor influencing BEU. While, change in envelop requirements has proven to determine relative changes in BEU (Cornick and Sander, 1994). Study (Li, Hong and Yan, 2014b), have proven that smaller buildings have lower EUIs and larger ones have higher EUIs than smaller buildings. Whereas, finding reveals that disrepair and faulty building envelope are considered by professionals as effective barriers. Result of envelope insulation has proven to save up to 23.5% cooling (Afang et al., 2014), energy used in the past. Hence, insufficient insulation will increase BEU.

Findings indicate that lack of funding could impede uptake of innovative technologies for managing BEU; and hence serve as barriers to BEP in both countries. A study (Berning, 2009; Nelson, 2012), has shown that increasing access to low cost funding will lead to more adoption of green technology and building energy codes. Besides, the lack of technical skill is considered (4<sup>th</sup>), as a barrier to FM that could hinder BEP. It corroborates past studies (Oyedepo, 2012), conclusions that the lack of trained personnel and EE professionals were critical barriers to BEP.



Quest-surv2 identified use of model as effective technical tool (RIA= 209; 5<sup>th</sup>); and lack of appropriate tools as a most critical barrier to FM practice (RIA= 294; 1<sup>st</sup>) that could hinder BEP. A recent study (Lee et al., 2015), demonstrated how the function of modelling via EnergyPlus simulation aided commercial building retrofits in reducing energy usage. Contrariwise, lack of knowledge of EE measures; as it has been previously cited (Oyedepo, 2012), amongst other barriers to the development of EE in Nigeria.

Finally, the study result indicates that lack of senior management commitment could serve as barriers to BEP in both countries. Similarly, a recent study (Johansson, 2015), cited it as a barrier; and indicated how networking amongst energy managers helped influenced Swedish steel plants improved energy efficiency.

### 7.3.15 Summary

The study investigated technical, managerial and operational solutions based on professional judgement. It was discovered that FMs play dominant roles in effecting the six sections of SBM (MPFB, MEFF, FEM, FWM, FRERPMR and MMSP) in the organisation. Also, SP and an executive action plan on BEE were considered as enhancing factors for BEP. Whilst, some key functions of FM (energy reduction programmes; efficient switching, lighting & equipment; HVAC matching; energy audit etc.) used in improving BEP were identified.

The FM practitioners also identified some of the barriers to BEE and FM's roles in the workplace. The lack of framework for reducing energy expenditure and awareness of EE measures; inefficient occupant behaviour; and faulty envelop), were identified.

The identified technical solutions for BEP: efficient switching; HVAC matching; and regular assessment & benchmarking, were perceived effective critical solutions for reducing BEU. Also, BEMS & DAS; regular energy audit; management, use of the framework; and solar PV panel installations were considered effective. Whilst, identified management and operational solutions for improving BEP: regular maintenance & refurbishment; organisation's SP; regular physical walk-through & inspection (technical survey); strategic energy performance policy; and education & training were perceived as effective critical solutions.

Finally, the study established that the FMs perceived: electric energy use; lighting energy use; and BEUI as the strongest PMs based on their relative strength index. Whilst, the HVAC

indicator, BEUI and Operational rating were identified as the strongest KPIs; and established benchmark was the most preferred method for benchmarking.

## 7.4 QUALITATIVE ANALYSIS AND DISCUSSIONS: INTERVIEW-SURV4

### 7.4.1 Descriptive Analysis

The section presents the data analysis of the qualitative study based on interviews with CEOs and facilities managers (FMs) within case buildings. In whole, seven participants (Nigeria= 5 and UK= 2), were questioned. The demographic profile (Table 7:31), reveals the interviewees' profile for both the Nigeria and the UK participants. Nonetheless, all case buildings are mapped in the audience except for Bldg102, which interview could not apply within the time frame in Nigeria.

*Table 7:31: Interview Demographic Profile.*

Interview Demographic Profile				
Interview ID	Bldg. ID	Location	Gender	Position
Case01	Bldg101	Nigeria	Male	FM
Case02	Bldg104	Nigeria	Male	CEO
Case03	Bldg105	Nigeria	Male	CEO
Case04	Bldg103	Nigeria	Female	CEO
Case05	Bldg103	Nigeria	Female	CEO
Case06	Bldg206; 207; 208; 209 & 210	United Kingdom	Female	FM
Case07		United Kingdom	Male	FM

This section contributes to answering the following research questions

- What are the critical factors influencing BEP in Nigeria and UK?
- What are the barriers and drivers to BEU and its EEP?

The section will also help to further validate findings from quantitative studies; and achieve the objective of identifying the relationship and independence between these critical factors. The participants' perception is examined under framework eight contextual factors and seventeen reflective indicators (sub-themes), based on the study literature. The research questions were transformed into focus prompts (Trochim, 2007), as seventeen critical factors (Table 7:32). They were asked the same eighteen questions under specific factors. Thereafter,

thematic analysis (Gillham, 2000; Akande, 2015), was used in the analysis and discussion of participants' view under each factor.

Table 7:32: Interview Framework

Interview Framework and Prompts with Targeted Study Objectives				
SN	Interview Questions	Context: Main Theme	Prompts: Sub-Theme	Targeted Objectives
1	What do you understand by global warming, CC and building CO <sub>2</sub> emissions?'	Climate	Climate change, adaptation/ mitigation	*Identify Critical Factors affecting BEP in Nigeria and the UK;  *Identifying the relationship and independence of these critical factors;  *Identify PMs/KPIs ditto;  *Identify barriers & drivers to BEEP; and  *Identify methods of using SP and FM to drive low carbon goal in existing Office buildings.
2	Do you have problem with estimated bills and how do you monitor your energy use	Management Policy	Strategic Energy Mgt (SEM)- Estimated billing Method	
3	Is maintenance of generators or BEU a management issue in the organisation?		Facilities Management (FM)	
4	Do you have a sustainability policy statement; and what is your business ethos?		Sustainability Policy (SP)	
5	How would you rate this building comfort?	Operational	Comfort	
6	What is the relevance of technologies in this building?		Technologies	
7	Do you have dedicated staff assigned to FM and energy use?		FM Department/ FM Roles	
8	How do assess and monitor your BEU?		Energy Assessment Metrics- MPs/KPIs	
9	In what way can BEU be manage more efficiently?	Sustainable Building Mgt. (SBM) - BAM	Built Asset Mgt.- BAM	
10	What are the challenges facing facilities managers?	Barriers and Drivers	FM	
11	What are the barriers & drivers to sustainable management of BEU?		SBM Energy Use	
12	What can be done to improve energy supply to this building?		Building Energy Supply	
13	What are the problems associated with energy supply chain (grid electricity to diesel supplies)?	Business Practice	Energy Supply Chain	
14	What is opinion about business as usual in energy supply chain?		Corruption	
15	What is your take on Nigeria oil & gas politics and BEU?	Regulatory Energy Policy framework	Oil & gas	
16	What is your take on corruption as barrier to regulatory policy effectiveness in terms of BEU?		Corruption	
17	Is there a regulatory energy policy and building energy code in this country?		Regulatory Energy Policy	
18	What is your take on alternative energy sources like solar PV panels, solar thermal?	Low-Zero Carbon- LZC Options	Renewable Technologies	

Result for parent node's matrix (coding) for locations indicates that model variables: operational, barriers & drivers, business practices, climate, regulations, management policy, LZC except cultural issues were identified as being relevant in both countries. Also, result on child node's matrix (coding) for locations (Figure 7.12 and Figure 7.13), indicates that in both countries, factors such as: FM, SEM, SP, technology, regulatory policy, assessment metrics,

corruption, building energy supply, BEU, energy supply chain, renewable, FM department/roles, comfort, and management policy were considered critical factors.

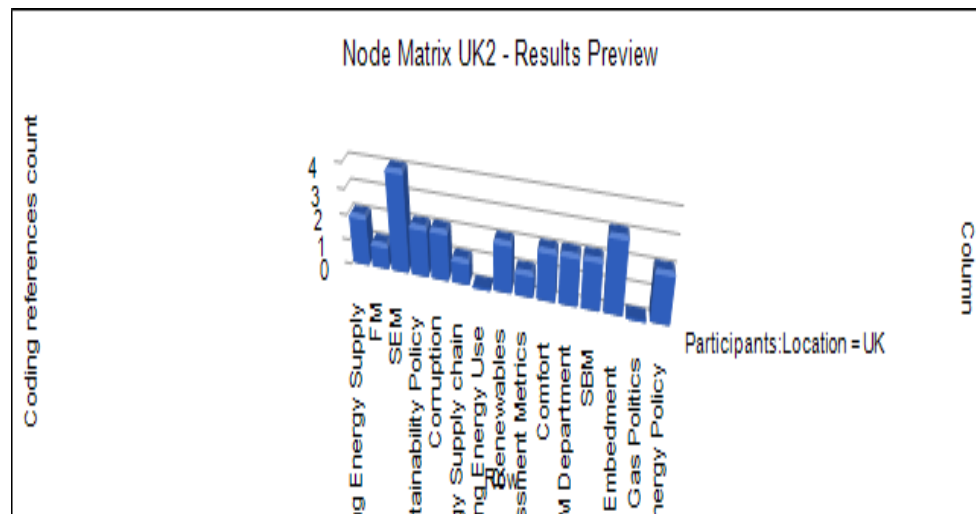


Figure 7.12: Node Matrix- UK

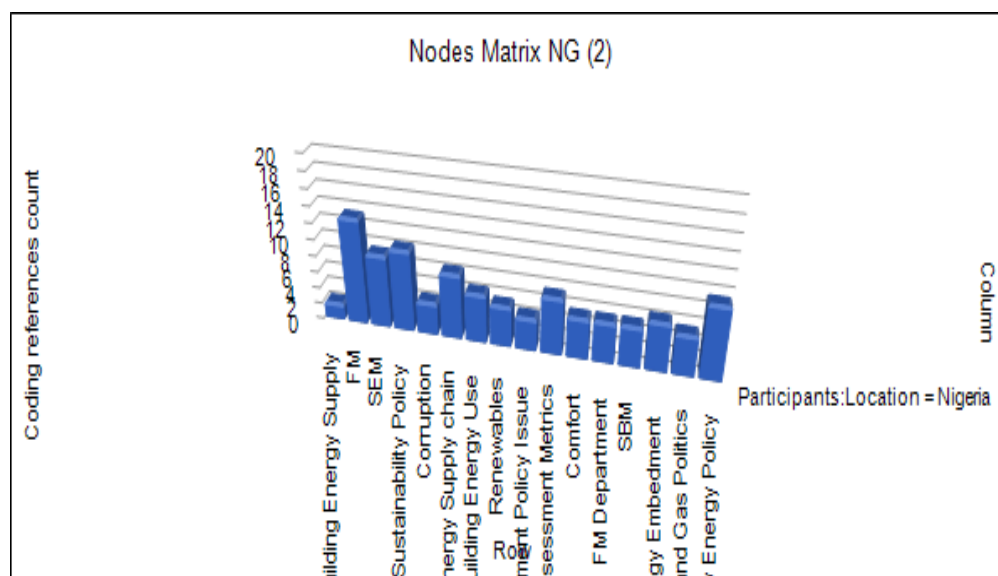


Figure 7.13: Node Matrix- NG

The result of the coding references counts indicated that these issues are more pronounced in Nigeria compared to the UK. Nevertheless, the impact of oil & gas politics and problems in BEU is peculiar to the Nigerian setting.

Cluster analysis was further performed via word frequency query for the 100 most used words by participants illustrated (Figure 7.14).



Figure 7.14: Study's most Commonly Used Words during Interviews

#### 7.4.2 Summary of Interview Result

The results (Table 7:33, Table 7:34, Table 7:35 and Table 7:36), based on detailed analysis of participants' opinion (in Appendix26), indicate that building energy codes, management policy issue, electricity supply, and cost associated with estimated bills featured prominently during the interviews. Likewise, other prominent issues identified are: staff of power companies, corruption, generators, and problems connected with fuel supply in Nigeria, etc.

Table 7:33: Summary of Interview Result1

Summary of Interview Result based on Sub-Theme and Target Objectives (1)		
Sub-Themes	Critical Factors that affect BEP	Relationships
1. Climate Change (CCH) and Building Energy Used (BEU)	<p>Participants established:</p> <ul style="list-style-type: none"> <li>➤ Strong awareness and understanding of CCH, and</li> <li>➤ Its links with energy use in buildings.</li> <li>➤ Use of generators</li> <li>➤ HVAC usage</li> </ul>	<p>They assert that:</p> <ul style="list-style-type: none"> <li>➤ BEU leads to CO<sub>2</sub> emissions and consequent CCH</li> <li>➤ Emissions from Generators</li> <li>➤ Energy intensity of air conditioners and radiators</li> </ul>
2. Management Policy	<p>Major problems reported by participants (Nig. &amp; UK):</p> <ul style="list-style-type: none"> <li>➤ Sustainable policy (SP),</li> <li>➤ Operational FM, and</li> <li>➤ Strategic energy Mgt. (SEM)</li> <li>➤ Energy supplier estimated billing policy</li> </ul>	<p>Critical barriers that affect the following:</p> <ul style="list-style-type: none"> <li>➤ Strategic energy planning,</li> <li>➤ Operational FM</li> <li>➤ Sustainable management of case buildings</li> <li>➤ Estimated billing lead to sharp practices especially in Nigeria</li> </ul>
I. SEM	<p>The Nigeria and UK Interviewees agreed that:</p> <ul style="list-style-type: none"> <li>➤ Estimated billing is a common practice in both countries</li> <li>➤ A critical barrier</li> <li>➤ It's often associated with outrageous bills</li> </ul>	<p>The primary cause for the high incidence of estimated billing use:</p> <ul style="list-style-type: none"> <li>➤ Poor energy management in Nigeria</li> <li>➤ Corruption</li> </ul>
II. Operational Facilities Management (FM)	<p>Participants cited (Nig. &amp; UK):</p> <ul style="list-style-type: none"> <li>➤ Reliance on Generators use</li> <li>➤ Organisations' lack of routine repair and maintenance plan for generators, and</li> <li>➤ Often, use of non-technical staff and unskilled technicians.</li> <li>➤ Operational FM is a management issue</li> </ul>	<ul style="list-style-type: none"> <li>➤ Operational FM issues are more of critical barriers to the Nigeria case buildings than the UK cases.</li> <li>➤ The high incidence of power outage is linked to heavy reliance on generator use in Nigeria</li> </ul>
III. SP	<p>Participants cited it as:</p> <ul style="list-style-type: none"> <li>➤ Critical driver for sustainable management of BEU and improvement of BEP;</li> <li>➤ UK buildings are managed with environmental management policy, and energy management plan as strategic documents;</li> <li>➤ None exist for all the Nigeria buildings. Rather, promote the values and practices of sustainability with sound corporate ethos</li> </ul>	<p>Interviewees linked SP document with:</p> <ul style="list-style-type: none"> <li>➤ SEM and;</li> <li>➤ Improvement in BEP</li> </ul>

Table 7:34: Summary of Interview Result2

Summary of Interview Result based on Sub-Theme and Target Objectives (2)		
Sub-Themes	Critical Factors that affect BEP	Relationships
3. Operational Issues	Participants perceived the following critical driver factors: <ul style="list-style-type: none"> <li>➤ Perceived comfort</li> <li>➤ Embedded technology,</li> <li>➤ FM's roles and</li> <li>➤ Energy assessment metrics</li> </ul>	The drivers are linked to: <ul style="list-style-type: none"> <li>➤ BEU reduction and</li> <li>➤ Improved BEP</li> </ul>
I. Comfort	<ul style="list-style-type: none"> <li>➤ Comfort rating for most Nigeria case building is fair, but those of the UK are good.</li> <li>➤ However comfort is driven by continuous cooling and heating in both countries.</li> </ul>	<ul style="list-style-type: none"> <li>➤ It was linked to</li> <li>➤ High BEU,</li> <li>➤ high energy cost</li> <li>➤ Frequent generator use, and</li> <li>➤ CO<sub>2</sub> emission</li> </ul>
II. Technology	Results revealed that: <ul style="list-style-type: none"> <li>➤ The UK case buildings are technologically embedded,</li> <li>➤ The Nigeria cases lack most identified technologies</li> <li>➤ Technology is very relevant in BEP and that they are useful for reducing BEU</li> <li>➤ Technology compliment human energy efficient habits</li> </ul>	Embedded technology is linked to: <ul style="list-style-type: none"> <li>➤ Energy saving;</li> <li>➤ Fight against behaviour control;</li> <li>➤ Data acquisition and storage; accurate billing;</li> <li>➤ Data analysis and forecasting; and</li> <li>➤ For strategic energy planning</li> </ul>
III. FM department/ Roles	Interviewees agreed that FM's energy Mgt. roles include: <ul style="list-style-type: none"> <li>➤ Ensuring of constant power supply,</li> <li>➤ Monitoring building energy supply and use, and</li> <li>➤ Performing constant routine and planned maintenance (generator).</li> </ul>	FM role is linked to <ul style="list-style-type: none"> <li>➤ Improved BEP, and</li> <li>➤ BEU reduction</li> </ul>
IV. Assessment Metrics	In Nigeria, the most commonly practiced PMs/KPIs are: <ul style="list-style-type: none"> <li>➤ BECI (£/m<sup>2</sup>),</li> <li>➤ BEUI (kWh/m<sup>2</sup>),</li> <li>➤ BEU/month (kWh/month), and</li> <li>➤ Prepaid metered billing.</li> </ul>	Participants in both countries agreed that the acceptable PMs/KPIs are: <ul style="list-style-type: none"> <li>➤ BEU, BEUI, BEC and BECI</li> </ul>
4. Sustainable Building Mgt. - Built Asset Mgt.	Participants agreed the following as critical drivers for improving BEP: <ul style="list-style-type: none"> <li>➤ Half-hourly energy use data monitoring and retrieval</li> <li>➤ Renewable uptake and government policy intervention</li> <li>➤ Constant and adequate grid electricity supply to buildings</li> </ul>	The linkage of positive correlation between: <ul style="list-style-type: none"> <li>➤ Grid electricity supplies to buildings; and BEE, energy cost reduction, increased productivity and comfort;</li> <li>➤ Energy monitoring and retrieval via; and efficient method of managing BEU;</li> <li>➤ Renewable uptake &amp; government policy interventions and BEP improvement</li> </ul>



Table 7:35: Summary of Interview Result3

Summary of Interview Result based on Sub-Theme and Target Objectives (3)		
Sub-Themes	Critical Factors that affect BEP	Relationships
5. Barriers and Drivers	<p>Most critical barriers are:</p> <ul style="list-style-type: none"> <li>➤ funding for investment in technologies and renewables</li> <li>➤ Occupant inefficient behaviour to FM roles in the UK</li> <li>➤ Power outages in Nigeria</li> </ul>	<p>Participants established the association between BEP: and</p> <ul style="list-style-type: none"> <li>➤ Funding for uptake of BEMS and renewable interventions</li> <li>➤ User's efficient behaviour</li> <li>➤ Energy security</li> <li>➤ Irregular electricity supply and FM performance</li> </ul>
I. FM	<ul style="list-style-type: none"> <li>➤ Inadequate and irregular national grid electricity supply is a critical barrier to FM in Nigeria</li> <li>➤ Citing occupant attitudes,</li> </ul>	➤ Ditto
II. Sustainable Mgt of BEU	<ul style="list-style-type: none"> <li>➤ Owners' business management style as additional barriers</li> <li>➤ Building refurbishment and lift's maintenance /repair as possible drivers</li> <li>➤ Lack of electricity supply</li> </ul>	<ul style="list-style-type: none"> <li>➤ Correlation between BEP and Owners attitude</li> <li>➤ BEP and maintenance culture</li> </ul>
III. Building Energy Supply	<ul style="list-style-type: none"> <li>➤ Poor energy supply to buildings; and high incidence of generator use in buildings in Nigeria</li> </ul>	➤ Correlation between BEP, power outages and use of generators
6. Business Practice	<p>Interviewees cited:</p> <ul style="list-style-type: none"> <li>➤ Peculiar problems in the Nigeria energy supply chain that are non-existent in the UK.</li> </ul>	<p>Interviewees linked the energy sector business practice in Nigeria with:</p> <ul style="list-style-type: none"> <li>➤ Poor energy supply chain</li> <li>➤ Corruption</li> <li>➤ Importation of generator</li> </ul>
I. Energy Supply Chain	<p>The result indicates:</p> <ul style="list-style-type: none"> <li>➤ Poor energy supply chain is a critical barrier</li> </ul>	<p>The poor supply chain is linked to:</p> <ul style="list-style-type: none"> <li>➤ Corruption,</li> <li>➤ Poor infrastructure,</li> <li>➤ Lack of maintenance,</li> <li>➤ Inefficiency</li> <li>➤ Fuel scarcity</li> <li>➤ Poor management</li> <li>➤ <u>Vandalisation</u> and stealing of electricity cables</li> </ul>
II. Corruption	<p>Interviewees opined that:</p> <ul style="list-style-type: none"> <li>➤ Corruption is a critical barrier factor in Nigeria</li> </ul>	<ul style="list-style-type: none"> <li>➤ Participants linked the underlying cause of corruption to importation of generators that is linked to certain clique or cabal.</li> </ul>



Table 7:36: Summary of Interview Result4

Summary of Interview Result based on Sub-Theme and Target Objectives (4)		
Sub-Themes	Critical Factors that affect BEP	Relationships
7. Regulatory Energy Policy	The Nigeria, participants listed the lack of: <ul style="list-style-type: none"> <li>➤ Building energy code, and</li> <li>➤ Regulatory policy/ institutional framework as barriers</li> </ul>	Participants linked associations between: The poorly structured and negative activities within Nigeria oil & gas with poor BEP
I. Oil & Gas Sector	<ul style="list-style-type: none"> <li>➤ Political / labour crises and strikes</li> </ul>	Poor implementation of institutional reforms and poor BEP <ul style="list-style-type: none"> <li>➤ Existence conspiracy theory and round tripping concepts for petroleum products</li> </ul>
II. Corruption	<ul style="list-style-type: none"> <li>➤ Respondents cited corruption as a factor impeding government regulatory policy</li> <li>➤ Sabotage</li> <li>➤ Nepotism</li> </ul>	They linked: <ul style="list-style-type: none"> <li>➤ Poor policy implementation with poor BEP</li> <li>➤ Non-implementation of existing framework and BEP</li> </ul>
III. Energy Policy	Results revealed: <ul style="list-style-type: none"> <li>➤ Building Code and institutional framework for BEP exist in the UK</li> <li>➤ None in Nigeria</li> </ul>	The UK participants established the link between: <ul style="list-style-type: none"> <li>➤ Regulatory policy, strict compliance, and improvement in BEP</li> </ul>
8. Low-Zero Carbon Options	Interviewees renewable energy interventions as critical drivers: <ul style="list-style-type: none"> <li>➤ Solar PV panels, solar thermal, inverter, low energy saving bulbs etc.</li> <li>➤ The inverter is peculiar to Nigeria, whilst</li> <li>➤ CHP is peculiar to the UK</li> </ul>	Result linked: Improved BEEP and uptake of renewable interventions

Specifically, the result of evaluation of participants' opinion on the various identified focus prompts based on audience questions is discussed in detailed infra.

### 7.4.3 Discussions

The findings indicate that study framework variables: climate, management policy, operations, SBM/BAM, barriers/drivers, business practices, regulatory policy framework and LZC interventions are found to be the critical issues associated with office BEU and its BEP.

The impact of Climate change (CCH) on BEU is established in past studies. Increase in climate region in Japan is proven to lead to increases in cooling and heating loads of office buildings (Shibuya and Croxford, 2016). This corroborated the assertion of study participants that

expressed causality in the relationship between climate change and buildings. Consequently, CCH leads to increased use of HVAC equipment in buildings for maintaining comfort (Huang and Gurney, 2016). Also, the finding indicates that government policy on BEP should be instituted as a solution.

The findings likewise revealed that respondents considered management policy matters such as SEM, FM and SP as critical factors that affect BEP. Particularly, SEM is associated with estimated billing methods from vendors in both countries. Nonetheless, UK *modus operandi* differs from that of Nigeria. Findings indicate that estimated bills are often outrageous irrespective of high frequency of electricity blackout especially in Nigeria, therefore should be eradicated (Okoro and Chikuni, 2007). This makes strategic planning for BEU becomes difficult as electricity cost is sporadic and volatile electricity supply persist. Result further confirmed that estimated bills could mar data analysis, subject it to errors, leading to non-robust and unreliable forecasting, and functions as critical barrier to SEM. Likewise, findings linked the practice of estimated billing method to corruption and poor energy management.

Findings suggest that operational FM activities are handled by mostly by CEOs and non-professionals in organisations in Nigeria. Nevertheless, the pattern is different from the UK organisations that have skilled professional FMs. Whilst, the concept of SP is embraced in both countries but there is need for senior Manager to advance the cause of sustainability in the Nigeria cases (Elmualim et al., 2010). Some of the organisation within the Nigeria case buildings does not have such policies. However, they all promote the values and practices of sustainability.

Environmental responsive image is also found to be desirable by organisations. Findings show that the UK's participants strongly advanced the role of their organisation's SP and its strategic drivers for improving its' estate BEP. Also, it shows that SP and strategic drivers inform of structure and staffing in the organisation is a prerequisite for reducing BEU and improving BEP.

Study findings identified operational issues such as comfort, technology, FM department/ roles, and energy assessment metrics as influencing factors on BEP. Findings show that Comfort is directly related to BEU (Taylor, Fuller and Luther, 2008). Most participants perceived their buildings to be comfortable however, finding reveals that comfort is driven constantly with air cooling / heating equipment with its heavy energy consumption demand (Ole Fanger, 2001).

Moreover, faulty design and wrong choice of construction materials were identified as major causes of discomfort in buildings during operations.

Technology was also identified as a critical factor that impacts BEP during operations. Results revealed that Nigeria case buildings lack modern technologies, as against UK buildings that are embedded with them. It was found that that technology compliment human energy efficient habits and improve comfort (Papantoniou, Kolokotsa and Kalaitzakis, 2015). They are utilized for energy saving; high comfort level; fight against behaviour control; data acquisition and storage accurate billing; data analysis and forecasting; and for strategic energy planning (Dounis and Caraiscos, 2009). Whilst, technologies drawbacks as revealed in findings are: faulty technology due to lack of repair; and lack of skill and competent staff for the installed technologies can aid poor BEP.

FM roles were revealed as a crucial factor that affects BEP (Goulden and Spence, 2015). These roles involve: ensuring of constant power supply, monitoring building energy supply and use, and performing constant routine and planned maintenance (generator). The choices of BEU and BEP assessment metrics is dependent upon peculiarity in Nigeria and UK. Participants in both states agreed that BEU, BEUI, BEC and BECI are the most acceptable PMs/KPIs (Deru and Torecellini, 2005).

SBM- BAM is another critical factor found to impact BEP. Findings revealed: energy monitoring and targeting via the use of robust technologies, adoption of green construction, government regulatory policy on BEE, building renovation, equipment maintenance/ repair, and renewable intervention as BAM strategies for achieving BEP (Altan, 2010; Gabe, 2016).

Barriers and drivers to operational FM, SBM energy use, and building energy supply are also found to be critical factors that affect BEP. Lack of funding for investment in technologies and renewables, and occupant inefficient behaviour are most critical barriers to FM roles in the UK. While short and irregular national grid electricity supply is a decisive barrier to FM that led to the use of generators in buildings in Nigeria. Almost the same barriers that affect FM roles also impact SBM energy use; the peculiar additions are: corruption, short term planning, and owners' business management style. The findings found building refurbishment and lift's maintenance /repair as drivers to SBM energy use.

Finding reveals that while building energy supply matches building demand in the UK that of Nigeria is marred with shortfalls due to frequent power outages. There is a severe lack of electricity supply to buildings, which contributes to high incidence of generators use in buildings (Ekpo and Bassey, 2016). Participants adduced this to sharp practices in the system and wrong mind-set of staffers of power vendor companies.

Business practices in Nigeria unlike in the UK, is another critical factor that is linked with poor energy supply chain and monopoly by certain cliques. Findings indicate that Nigeria energy supply chain is associated with corruption, poor infrastructure for network distribution, lack of maintenance, inefficiency, fuel scarcity and poor management (Saidu, 2011; Ekpo and Bassey, 2016). Whereas, in the UK, energy companies are better efficient to abide by standing vendor contract agreements. Likewise, the UK's energy supply practice allows for a broker as an intermediary that is not in existence in Nigeria.

Findings show regulatory energy policy is a critical factor that is influenced by activities in the oil and gas sector of both countries. Also, there is no building energy code in Nigeria unlike the UK. Whilst, some of the issues found in Nigeria involve: corruption, lack of regulatory policy and institutional framework (Wang et al., 2016). Nonetheless, the result indicates corruption as the main issue associated with policy regulation, poor policy implementation; non-performance of institutional framework; and sabotage of government reform programmes (Osoba, 1996). This is also linked to political cabal who profit from the energy crises.

Contrariwise, in the UK, there are regulatory frameworks with established institutions for monitoring, control and enforcement. The study found out UK case building organisation doesn't encounter regulatory compliance problem and they often surpass it (Pérez-Lombard et al., 2009). This was traced to the effects of regulation and compliance in the UK, which Nigeria can leverage on.

Finally, finding reveals the acceptance of LZC interventions in both countries. Particularly, renewable energy intervention such as solar PV panels, solar thermal, low energy saving bulbs and inverter are advanced by participants as the best methods of improving BEP (Omer, 2014; Ezema, Olotuah and Fagbenle, 2016). But the role of CHP as intervention is favoured in the UK.

#### 7.4.4 Summary

Seven semi-structured interviews were performed for CEOs, Owners and Facilities Managers within study ten case buildings in Nigeria and the UK. Thematic analysis was executed using the NVivo10.0 qualitative analysis software via coding. Thereafter, content analysis is used for prompt sub-themes (Gillham, 2000; Akande, 2015). The findings reveal that all study framework variables are critical components. Whilst the Nigeria case buildings are strongly affected by these contextual factors, the UK buildings are less affected by them.

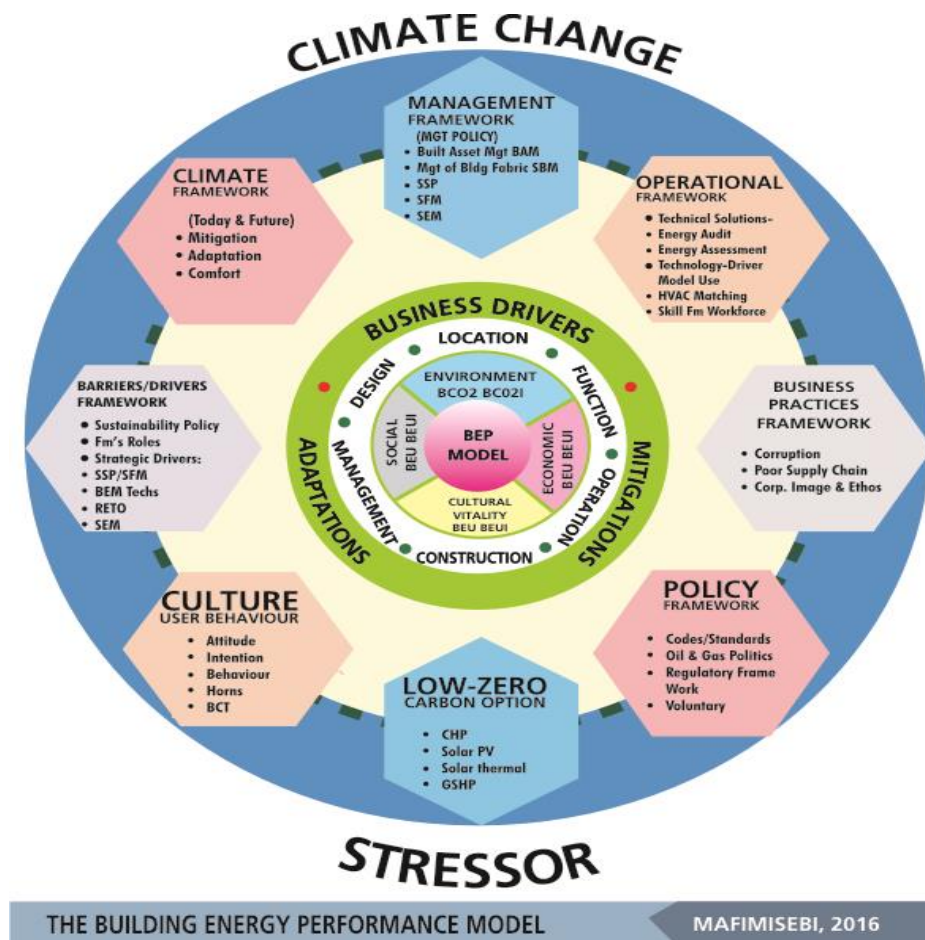


Figure 7.15: BEP Framework model.

It was also discovered that regulatory policy and institutional framework play a major role for the differences rather than culture in both countries. These confirm the findings in study phase one (energy performance of case buildings) and study phase two (Quest-Surv1 and 2). Finally, the three study's findings confirmed these factors to be associated as depicted by broken boundary lines (Figure 7.15); hence, it is necessary to further use SEQM to ascertain causality between them and to reduce them to most critical factors influencing BEP.

## 8 Chapter Eight: QUEST-SURV3- Model Validation via SEQM

### 8.1 INTRODUCTION

The study also presented the research framework to respondents in obtaining their views on structural component variables. The aim of this study is established along the premise that a model should be uncomplicated and easy to read. Hence should be comprehended by professional and non-professional within the organisation. Its role is to model respondents' view on solutions for improving building energy performance (BEP) based on current study identified critical factors.

The aim of the chapter is to validate the study model by:

- Determining if identified Sustainable building management (SBM) solutions for BEP fits into a structural/ measurement model based on study theoretical model
- Identifying possible co-axial relations and plausible causation between latent factors (including manifest variables) of the model
- Testing of the structural relationships (hypotheses) in structural model variables, and
- Finding out if data collected (based on observed variables) supports study theoretical model.

### 8.2 METHODOLOGY

The occupants of study's ten case buildings (in Nigeria and UK); and members of the International Facilities Management Association, were used as the sampled population. Online questionnaire via Survey-monkey platform was utilized for gathering information. In all, 250 questionnaires were sent out and a response of 120 based on 5-point Likert scale was received. The Cronbach's alpha result indicates Alpha of 0.798 and 0.886 on N (87) standardized items, which showed an acceptable strong reliability level at the acceptable alpha value of .70.

Data from this survey was not meant for SEQM analysis, rather analyse via chi-square statistics and traditional regression methods was planned, the SEQM analytical method was later adopted because of its obvious advantages established in the study. The data collected is used in building the measurement model; and later transformed into the structural models to see how

well observed variables line up with the constructs. The structural model formed the creation of paths upon, which hypotheses are tested.

### 8.2.1 Demographics

The result indicates about 68.9% of respondents (n = 119) are living in Nigeria, while 31.1% are living in the United Kingdom. The majority of the respondents (about 55.8%; valid N= 120) are staff of various organisations within case buildings in both countries. A third (24.2%; n = 29) of them are scholars. Whilst, about a tenth of the participants are facilities /property managers (10.8%; n = 13) and MDs/Owners (9.2%; n = 11).

The study theoretical model requires a critical mind in understanding the interrelationships between variables. Hence, the level of education of respondents is critical in this knowing. The result revealed about 91.6% (n = 119) respondents are educated up to B.Sc. Degree level. It translated to about 44.4% of the participant being educated up to B.Sc. Level, and 42.2% of Master's degree levels. Likewise, 2.5% of the respondents (n=3) are educated up to PhD level. Whilst, about 5.9% (n = 7) have professional certifications; and another 5.9% of them have GCE certificate. Still, another 3.4% of the respondents (n= 4) have other specialised degrees.

## 8.3 STUDY PREPOSITION

Theoretical priori knowledge is the use of BEP framework as operational based model by organisations (Figure 8.1). Based on managerial solutions (policies) propelled by strategic energy efficiency (EE) drivers, BEP model could be applied effectively as an operational tool (energy audit and assessment) for improving BEP. A stand-alone BEP model is not sufficient as operational based model. Thus, managerial policies driven by EEP strategies, and an operational energy monitoring and control intervention are needed to enable study BEP model be an effective operational tool.



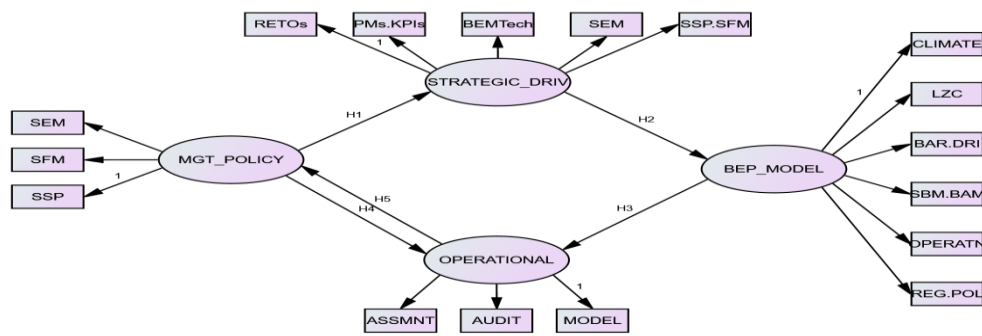


Figure 8.1: Study's Theoretical BEP Model

The prior knowledge is grounded on the investigation into organisations using study's ten case building. The Anglia Ruskin University's Estate and Facilities is chosen as a case sample for model application, because it has established functional FM department and operational management system. The Anglia Ruskin University (ARU) has an environmental management system plan certified through IMS International BS EN ISO 14001: 2004. The certification ensures compliance with environmental laws and improvement in environmental performance. ARU environmental sustainability covers building performance, energy and carbon management policy amongst others with detail objectives and targets in fulfilling policy commitments (ARU, 2016).

This exemplary application hinges on management, and advocacy of EE through a subset of energy management policy that is centred along the combination of strategic energy management (SEM), strategic sustainability policy (SSP), and strategic facilities management (SFM) policy. Such policy statements should have low carbon goals with quantifiable building energy use (BEU) and efficiency targets. A method and resource requirement statement (protocols, humanities and technologies), should also be an inbuilt piece of the energy management policy. ARU has carbon and energy management plan, which contains buildings' emissions compliance guidelines and objectives. This qualified it as an exemplary case study application. Furthermore, the policy action statement should be implemented through a subset of strategic drivers for transformation into achievable results.

A strategic scheme such as: renewable energy technologies (RETOs), performance metrics and key performance indicators (PMs/KPIs), building energy technologies (BEMTechs), SEM and



SSP/SFM, based on physical structures and staffing for driving BEP are needed to implement these management policies. Although, ARU does not have separate departments for such schemes, but it has key staff specialised to fit specific job description. Studies (Altan, 2010; Ma et al., 2012) have established that installation of RETOs and BEMTechs initiatives have resulted to about 58-100% level of successes, and different energy saving rates of about 5-46% in the past. Hence it is constituent of the theoretical foundation of the current study framework.

Use of standardised PMs and KPIs as a systematic method of building energy performance evaluation, have been linked to energy saving and improvement in BEP in past studies (Greensfelder, Fried and Crow, 2010; Wang, Yan and Xiaol, 2012). A clear, consistent, and accurate performance metrics help owners and facilities managers to build and operate more energy efficient buildings; and policy makers formulate purposeful performance goals and track progress towards them (Deru and Torecellini, 2005).

SEM has been advanced in extant literature (Ates and Durakbasa, 2012; Rudberg, Waldemarsson and Lidestam, 2013), as a combination of interrelated processes (operations, tactics, and strategies) needed to reduce building energy usage, cost and carbon emissions in an organisation. While, a policy driver like SSP/SFM in the form of integration of FM roles into managing facilities and strategic management level in an organisation, has been found to underpin the organisation's commitment to BEU reduction and low carbon emissions from facilities (Ikediashi, Ogunlana and Ujene, 2014). A combination of these factors has not been tested in past studies as being advanced in the current study.

For instance, the university estate and facilities department have an Environmental Manager, who is responsible for overall environmental sustainability, energy and carbon management, and technologies for accomplishing these ends. It has a BMS engineer who oversees facility's energy consumption and sees to performance metrics, compliance with their vendors. However, the strategy of aligning SP and SFM is lacking in the ARUP practices, and also, it doesn't have a separate renewable technology expert team.

Operational procedure for energy assessment and benchmarking including modelling and certification is linked to BEP improvement (EU CEN EPBD, 2002; CIBSE, 2006b; CIBSE, 2008). Therefore, the operational sub-model involves the strategic team carrying out the implementation and monitoring of interventions and overall BEU based on BEP model results

and other information sources (objective and subjective) for diagnosis. This help track, monitor and detect abnormality in BEU and BEP (Deru and Torecellini, 2005).

ARU action plan on energy management contains the responsibility of improving building scale of energy monitoring and targeting by incorporating half-hourly sub-meter with existing energy management software (ARU, 2016). ARU's environment, energy and carbon sustainable team represent an exemplary case for this study as is saddled with targets. However, it appoints independent energy assessors for its compliances purpose.

The best way to utilise all data (quantitative and qualitative) to improve BEP, is to consolidate the central BEP sub-model data with other sub-models (policy, strategy and operational procedure). The BEP model is central to the building energy compliance status, it stands for the overall BEP level in the interconnected model overall process. Herein, indexes of critical impact are indicated for the respective factor for improving BEP. The higher the squared multiple correlation of the BEP sub-model for a building the better its performance. The BEP model helps keep eyes on the overall energy performance of buildings which is missing in the ARU exemplary case.

In using the BEP model to accomplish the said purpose, the study therefore hypothesised as thus:

- I. There are no significant causal relationships between operational, management policy, strategic drivers and BEP model
- II. BEP model and operational or policy or strategic solutions are not moderated by the combined use of SSP and SFM.

The two models are offered to consider the two-way directional paths (H4 and H5 in Figure 8.1) created in between management policy and operational solutions vice visa.

#### 8.4 PROTOCOL: MEASUREMENT AND STRUCTURAL MODELS

The study adopted the procedure outlined by Blunch (2008) and Gaskin (2012), for performing exploratory factor and confirmatory factor analyses for the measurement and structural models.

It also performed structural modelling, hypotheses testing and discussion as a procedure in validating the model (Ko and Stewart, 2002; Gaskin, 2012; Longo, 2015).

## 8.5 EXPLORATORY FACTOR ANALYSIS.

The study variables (56nrs) were subjected to exploratory factor analysis (EFA) using IBM SPSS22. The utilization of EFA made it possible to determine if these sets of variable measure the hypothesised constructs for BEP model in improving BEP. Also, it clarifies how underpinning factors (latent) caused variance in the measured variables; and the certainty of the accuracy of the measurement (Gaskin, 2012).

Hence, as corroborated by some authors (Blunch, 2008; Le Dang et al., 2014), the evaluation of the validity of all measurement models were carried out first, before the testing of all structural models were accomplished afterward. The EFAs were performed to check for correlation of observed variables, their expected combined loadings, and criteria for validity and reliability are being met (Blunch, 2008; Hair et al., 2010; Gaskin, 2012).

### 8.5.1 Choice of Extraction Method for EFA

The usage of SEQM in this study targeted to find out, amongst others, the meaning of correlation between different variables of hypothetical structures. Hence, the need for the appropriate extraction methods becomes very important. Past study (Gaskin, 2012), illustrated the difference between principal component analysis (PCA), principal axis factoring (PAF), and maximum likelihood (ML). Gaskin (2012), explained that principal component analysis reflects all the common and unique variances; principal axis factoring considers only common variances; and maximum likelihood makes best use of differences between factors and provide a model best fit estimate.

The current study used the maximum likelihood factoring method as it provided the variances between all factors and best fit for the models. This aligned it with the maximum likelihood method used in AMOS software for CFA and SEQM (Blunch, 2008; Gaskin, 2012).

### 8.5.2 EFA based on Maximum Likelihood Estimation

The 56 variables were analysed using maximum likelihood extraction methods for factor reduction, and extraction based on Eigenvalue of 1.0. This was performed in this two-stage phase to group these variables into the underlying factors in the measurement models. The factors were further rotated with Promax-Kaiser Normalisation method. Whilst, their co-efficient were subjected to absolute value of 0.30, with those below it deleted (Gaskin, 2012).

All factors having eigenvalue  $> 1.00$ , were specifically retained. The cumulative variance for each construct is expressed by its Eigen value (Sen, Roy and Pal, 2015). Extraction based on Eigenvalue of 1.0, produced a four-factor model with extraction sum loading of 67.32%, indicating that the four-factor model explained 67.32% of the variance. It obtained a KMO sampling adequacy of 0.86; and Bartlett's test of Sphericity Approximate Chi-Square ( $\chi^2$ ) (136) of 1388.36. The model fit well at goodness of-fit test of  $\chi^2$  (74) = 135.11 at 0.00 significance. The extracted four latent constructs are strategic drivers, operational, managerial policy and BEP model.

Table 8.1: Study Variable Communalities.

Study Variables Communalities <sup>a</sup>				
SN	Initial Study Variables (Acronyms)	Study's Observed Variables (Full Meaning)	Initial	Extraction
1	SMEAN(OP_Model.use)	Modelling Tool- (Model Use) for Operational FM	0.570	0.560
2	SMEAN(OP_Engry.Audit)	Energy Audit (Engry.Audit) Ditto	0.709	0.717
3	SMEAN(OP_Assmnt)	Energy Assessment (Assmnt) Ditto	0.768	0.928
4	SMEAN(MGL_SSP)	Strategic Sustainability Policy- SSP as Managerial- Mgl. Solution	0.685	0.705
5	SMEAN(MGL_SFM)	Strategic Facilities Management- SFM as Mgl. Solution	0.730	0.897
6	SMEAN(MGL_SEM)	Strategic Energy Mgt.- SEM as Mgl. Solution	0.562	0.561
7	SMEAN(DRI_SSP.SFM)	Combined SSP and SFM (SSP.SFM) as Driver to BEE	0.715	0.704
8	SMEAN(DRI_PMs.KPIs)	Performance Metrics and Key Perform. Indicators (PMs.KPIs) as Driver	0.730	0.764
9	SMEAN(DRI_RETOs)	Renewable Energy Technologies (RETOs) as Driver to BEE	0.695	0.713
10	SMEAN(DRI_SEM)	Strategic Energy Mgt (SEM) as Drivers to BEE	0.725	0.774
11	SMEAN(DRI_BEMTechs)	Building Energy Mgt. Technologies (BEMTechs) as Driver to BEE	0.680	0.706
12	SMEAN(F.Model_Climate)	Climate Context Sub-Model- Building Mitigation and Adaptation Measures	0.503	0.473
13	SMEAN(F.Model_SBM.BAM)	SBM-BAM Context Sub-Model	0.682	0.563
14	SMEAN(F.Model_OP)	Operational Context Sub-Model	0.724	0.633
15	SMEAN(F.Model_BAR.DRI)	Barrier/Driver Context Sub-Model	0.605	0.578
16	SMEAN(F.Model_Policy.Frmwk)	Regulatory Policy/ Inst. Framewk Context Sub-Model	0.622	0.660
17	SMEAN(F.Model_LZC.Solns)	LZC Intervention Context Sub-Model	0.569	0.509
*Extraction Method: Maximum Likelihood via Promax with Kaiser Normalization Rotation.; *Eigenvalue (4 factors extracted with extraction sums of squared loading of 67.32% Cum.)				

The communalities for all factors were checked against their latent variables. This helped in knowing, which part of the variance of measurement a variable shared with the one latent variable (Blunch, 2008). All factors with absolute communalities value below 0.400, were deleted in reducing and refining extraction process. Eventually, a 17-variable measurement and structural models are achieved. While their factor's communalities for the extraction ranges from 0.47 to 0.93 (Table 8:1).

## 8.6 MEASUREMENT MODEL SPECIFICATION

The measurement model reveals the relationship between study underlying constructs and their respective reflective indicators; and that between the extracted constructs of the 4-factor model. The emergent model is a reflective measurement model that includes reflective four latent factors as sub-models. Therefore, the model's detail involves its estimate of standard regression weights that differentiate constructs from observed indicators.

### 8.6.1 EFA Assumptions

Current study performed several validation tests as procedure of meeting requirement of the following EFA assumptions.

#### *I. Multicollinearity*

Multicollinearity test is performed based on regression method using SPSS. The result indicates most variable tolerance is < than 1.00, ranging from 0.270 (Driver\_PMs. KPIs) to 0.497 (OP\_Model use). Also, their VIF is < than 10.00, this ranges from 3.740 (Driver\_PMs. KPIs) to 2.324 (OP\_Model use). Consequently, the assumption of Multicollinearity was not violated in the current study.

#### *II. Linearity*

Likewise, the SPSS scatter plot is used to indicate the squared correlation between measurement model variables. A 16 x 16 (256nrs) squared correlation scatter plot is achieved, which reveals most of the variables have linear relationships. Hence, the supposition of linearity amongst variables is upheld.

#### *III. Homoscedasticity Test*

A scatter plot of regression standardised residuals against regression standardised predicted values based on regression is applied. Result indicates almost a straight line with slight curves, meeting the condition of homoscedasticity based on the lowest line.

#### IV. Invariance Test

Study variables are checked for discrepancies using invariance test. The variance of any one of the variable is clearly not greater than ten times the variance of any other. Their variances (Table 8:2), ranges from 0.305 (Driver\_BEMTechs) to 0.773 (OP\_Assmnt). Result indicates study variables passed the invariance test.

Table 8:2: Invariance Table

Descriptive Statistics		
	N	Variance
OP_Model.use	120	0.701
OP_Engry.Audit	120	0.664
OP_Assmnt	120	0.773
MGL_SSP	120	0.535
MGL_SFM	120	0.563
MGL_SEM	120	0.660
DRI_SSP.SFM	120	0.462
DRI_PMs.KPIs	120	0.412
DRI_RETOS	120	0.346
DRI_SEM	120	0.351
DRI_BEMTechs	120	0.307
F.Model_Climate	120	0.643
F.Model_SBM.BAM	120	0.521
F.Model_OP	120	0.532
F.Model_BAR.DRI	120	0.454
F.Model_Policy.Frmwk	120	0.714
F.Model_LZC.Solns	120	0.588
listwise	120	

#### V. Positive Definiteness

Factor analysis is likewise used in specification of study constructs, by ensuring that four constructs exist as specified. The correlation matrix reveals that variables' determinant of correlation (1.98E.006) is not equal to zero but close to it. Thus, the assumption of positive definiteness has not been violated.

#### VI. Unidimensionality

The factor loadings between variables and a factor are checked for unidimensionality. All variables having the highest loading are constrained uniformly under each construct. It allowed unidimensionalised to be achieved for constructs. All the constructs have with good loading.

### 8.6.2 Normality Test

The Mahanobis distance method is applied to check for outliers. This helps to control outliers and heterogeneity of data in maintaining normal distribution. Absolute values for kurtosis (<

7) and skewness (-2 to +2), are used as criteria for acceptance of normality for endogenous variables (Byrne, 2010; Jenatabadi and Ismail, 2014). Result (Table 8:3), indicates study skewness range from -1.219 to -0.18, and the kurtosis lies between -0.127 to +3.398. Herein, condition for normality assumption is fulfilled; hence, normality of study endogenous variables is acceptable.

Table 8:3: Normality Test

Variable	Assessment of normality					
	min	max	skew	c.r.	kurtosis	c.r.
OP_Model.use_1	1	5	-0.927	-4.147	1.557	3.481
OP_Engry.Audit_1	1	5	-1.095	-4.898	2.06	4.607
OP_Assmnt_1	1	5	-0.979	-4.378	1.256	2.808
MGL_SSP_1	1	5	-1.045	-4.672	2.419	5.408
MGL_SFM_1	1	5	-1.219	-5.453	3.349	7.488
MGL_SEM_1	1	5	-1.192	-5.331	1.947	4.353
DRI_SSP.SFM_1	1	5	-1.109	-4.957	3.398	7.599
DRI_SEM_1	2	5	-0.392	-1.752	0.866	1.936
DRI_BEMTechs_1	2	5	-0.399	-1.782	1.556	3.479
DRI_PMs.KPIs_1	2	5	-0.784	-3.507	1.9	4.249
DRI_RETOs_1	3	5	-0.18	-0.805	-0.127	-0.285
F.Model_Policy.Frmwk_1	1	5	-1.116	-4.99	1.858	4.156
F.Model_OP_1	1	5	-1.096	-4.901	2.584	5.778
F.Model_SBM.BAM_1	1	5	-1.124	-5.027	2.82	6.306
F.Model_BAR.DRI_1	1	5	-0.994	-4.444	3.173	7.095
F.Model_LZC.Solns_1	1	5	-0.786	-3.513	1.359	3.039
F.Model_Climate_1	1	5	-1.201	-5.372	2.495	5.579
Multivariate					220.765	47.575

### 8.6.3 Sampling Adequacy Test

The study measured the appropriateness of the seventeen variables grouped into 4nrs underlying constructs. The KMO test and Bartlett's test of Sphericity are applied as rule of thumb for sampling adequacy in establishing variables' relationship (Table 8:4). All study sampled variables' KMO test lies within 0.7 and 0.9, indicating within acceptable good and great level in ranges. Whilst, the Bartlett's test of Sphericity with chi-square ( $\chi^2$ ): = 390.112 (SBM model); 425.264 (drivers); 205.164 (operational); and 186.49 (managerial), all are significant at < than 0.001 significance level.

Table 8:4: Measurement Model EFA Result.

MEASUREMENT MDOEL(MM) FOR SBM HOLISTIC 4-FACTOR MODEL: Pattern Matrix <sup>a</sup>				
	Factor			
	1	2	3	4
CONSTRUCTS	BEP MODEL	STATEGIES	OPERATIONAL	MGT. POLICY
KMO Sampling Adequacy	0.825	0.902	0.717	0.725
BARTLETT TEST OF SPHERICITY	390.112	425.264	205.164	186.49
Significance	0.000	0.000	0.000	0.000
ALPHA RELIABILITY	0.881	0.924	0.882	0.875
F.Model_Policy.Frmwk	0.866			
F.Model_OP	0.774			
F.Model_SBM.BAM	0.747			
F.Model_BAR.DRI	0.743			
F.Model_LZC.Solns	0.663			
F.Model_Climate	0.627			
DRI_SEM		0.936		
DRI_BEMTechs		0.846		
DRI_PMs.KPIs		0.842		
DRI_RETOs		0.784		
DRI_SSP.SFM		0.733		
OP_Assmnt			0.977	
OP_Enrgy.Audit			0.821	
OP_Model.use			0.657	
MGL_SFM				0.954
MGL_SSP				0.752
MGL_SEM				0.737
SUM OF FACTOR'S LOADINGS	4.420	4.140	2.455	2.443
AVERAGE FACTOR'S LOADINGS	0.737	0.828	0.818	0.814
AVE (%) Average Variance Extracted (value of Squared Multiple Correlation)	0.543	0.686	0.669	0.663
MM_SBM HOLISTIC 4-FACTOR MODEL (OVERALL): *KMO Sampling Adequacy = 0.860; *Bartlett test of Sphericity (Chi-Square) = 1388.36; df= 74; Sig. = 0.000. *Goodness-of-Fit test (Chi-Square)= 135.106; df= 74; Sig.= 0.000; and Cronbach's Alpha= 0.907 (N= 17items)				
Extraction Method: Maximum Likelihood.				
Rotation Method: Promax with Kaiser Normalization. <sup>a</sup>				
a. Rotation converged in 6 iterations.				

#### 8.6.4 Reliability Test

A composite reliability (CR) based on Cronbach's alpha reliability is performed on variables under the extracted factors. Result (table 8.4), indicates all four factors' Cronbach's alpha coefficient is > 0.70 (Nunnally and Bernstein, 1994; Ko and Stewart, 2002). The factors' coefficients are: BEP ~ 0.881; strategies ~ 0.924; operational ~ 0.882; and managerial ~ 0.875. It confirms all observed variables as reflective indicators of respective factor (latent).

#### 8.6.5 Factorial Validity Test: Convergent and Discriminant validity.

Factorial validity was established through convergent and discriminant validity (Lowry, Gaskin and Moody, 2015). Most study factors' loading is > than 0.70, with energy audit (0.977); MGL\_SFM (0.954); DRI\_SEM (0.936); and model policy framework (0.866) having the highest loading. However, Model\_LZC (0.663); Model\_Climate (0.627); and OP\_Model use (0.657), are < than 0.70. A variance higher than 0.50 indicates adequate convergence; hence study's FL range (0.627 to 0.977) meets adequate convergence (Chou et al., 2015). The factor loadings (FLs) are the correlation between the observed variables and respective constructs.

Composite or construct reliability (CR) is used as another measure for convergent validity. The four latent variables have CR values > than 0.7; BEP (0.737); strategy (0.828); operational (0.818); and policy (0.814). The CR, reveals how much of the variance that can be explained



by the study variables. Convergent validity is used to determine if factors for a construct are related and their reflection of a construct converges. A CR ( $R^2$ ) values between 0.50 and 0.70 is acceptable as the moderate standard (Hair et al., 2010).

The average variance extracted (AVE) is the amount of variance captured by a construct in relation to the variance due to random measurement error (Sen, Roy and Pal, 2015). Result also established all factors' AVE: BEP (0.543); strategy (0.686); operational (0.689); and policy (0.664), are greater than 0.50 (Segars, 1997; Jenatabadi and Ismail, 2014).

A discriminant validity involves ascertaining that those constituents that are not presupposed to be associated, are not affiliated. The factor correlation matrix indicates that the correlation is less than 0.70; FLs are  $\leq$  than 0.70; and there is no problematic cross loading (Gaskin, 2012). However, all factors' correlation is positive. Result indicates BEP model is strongly correlated with strategic drivers (0.550), but has weak correlation with operational (0.239) and managerial policy (0.294). Strategic driver is strongly correlated with BEP model (0.550) and management policy (0.493), but is weak with operational (0.296). Also, operational solution is only strongly correlated with managerial policy (0.433), whilst, managerial policy is strongly correlated with strategic drivers (0.493) and operational (0.433) but weak with BEP model (0.294).

#### 8.6.6 Common Method Bias Test

The study established common-methods bias ("mono-method bias") for variables' EFA and CFA. This is to ensure that a negative factor is not included in the remaining data for the analysis (Lowry, Gaskin and Moody, 2015). The correlation matrix for constructs in measurement and SEQM models are checked in ensuring that none was above 0.90. A correlation above 0.90 is evidence that there might be a common-method bias. All study constructs' correlation matrix's values were below the upper limit of 0.90 (Pavlou, Liang and Xue, 2007; Lowry, Gaskin and Moody, 2015). Hence, common method bias might not likely be a critical concern in current study's models.

### 8.7 CONFIRMATORY FACTOR ANALYSIS

The confirmatory factor analysis (CFA) aimed to test study's hypotheses regarding the factors' structure. The models (measurement and the sub-models), are tested for consistency with the

collected observed data (Hui, 2011). The CFA examined their expected combined loading, reliability, validity, goodness of fits and other model fit criteria (Ko, Hwang and Kim, 2013).

#### 8.7.1 Model Fit Test

The initial model is based on two theoretical concepts namely: BEP model as a tool for improving BEP (a single-factor model); and the solution sub-models (drivers, managerial, and operational), needed for making a BEP model an effective BEP tool.

The EFA reduced the BEP model initial eight contextual indicators to six. Culture and business practice components of a study framework yielded low commonalities ( $<0.30$ ) and low FLs (0.40), hence, they are dropped from the analysis. The inter-item correlation matrix indicates very strong positive associations between all reflective indicators for the BEP model. Their correlation ranges from 0.796 to 0.394, the highest being; final Model\_Operational to model\_SBM.BAM (0.796), and to model\_Policy.Frmwk (0.653). The only weak relationship is between final model\_LZC.solns and model\_SBM.BAM (0.394). This could be due to LZC solution partial effects on the BAM, as it could help in reducing CO<sub>2</sub> but not energy consumption of buildings.

#### 8.7.2 Model Specification

The single-factor BEP model is combined with other solution sub-models based on the EFA (Table 8:5). This is grounded on prior theoretical knowledge that BEP model alone cannot achieve its purpose, unless utilized as a tool for implementing identified operational, management and strategic solutions for BEP.

The current measurement model has four distinct single-element sub-models, namely: the building energy performance (BEP) model, management policy, operational and strategic drivers' models. The construct models based on priori theoretical knowledge and data collected, are merged with the BEP model to achieve the measurement and structural models.

##### *I. Construct Models: Sub-models*

IBM Amos 23 is used to build the structural equation modelling and performed CFA on both construct and measurement models. The initial and ultimate results for the four constructs and seventeen indicators measurement model is derived through CFA. Results (Table 8:5 and

Figure 8.2; Figure 8.3; Figure 8.4; Figure 8.5), indicated good model fit manifestations. The residual covariance between the four construct models have most of their standardised residuals < than absolute 2.0 value. Hence, the SBM model can be adjudge correct (Joreskog and Sorbom, 1984).

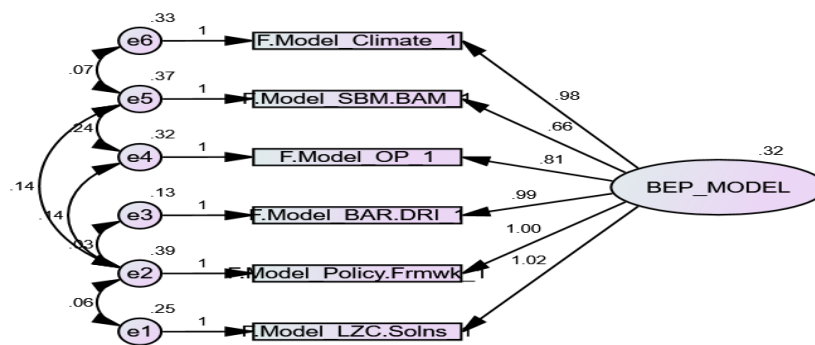


Figure 8.2: BEP Construct Model

The result of the structural model confirms acceptable fit for the final BEP construct model (figure 9.2 above). Though, its initial model result indicates poor fit at non-significance indices ( $\chi^2$  (7.906) = 71.151; and CMIN/DF= 7.906; p-value= 0.000; RMSEA= 0.241 and PCLOSE= 0.000). After modification, its fit improved to acceptable ( $\chi^2$  (3) = 2.522; CMIN/DF= 0.751; p-value= 0.522; RMSEA= 0.000 and PCLOSE= 0.637) at significance level.

Its Bollen-Stine bootstrap value increased from p= 0.020 (initial model) to p= 0.617 (modified model). While standardised RMR increased from 0.079 (initial model) to 0.018 (final model), indicating acceptable overall independent sub-model fit collected data.

The BEP final model indicators' coefficient (R), coefficient determination ( $\beta$ ), Z-value (Critical ratio), and T-test values are all significance at values  $< 0.0001$ . The high Z-scores also implied all BEP variables have their SD ( $\mu$ ) above their means ( $\mu$ ). For example, all paths' coefficient is significant; the constructs' path correlation coefficient indicates that BEP to BAR\_Dri has the highest coefficient of determination ( $\beta = 0.840$ ;  $Z = 6.654$ ; T-value = 6.664; and p-value  $< 0.0001$ ). Whilst, the lowest is BEP to SBM\_BAM ( $\beta = 0.527$ ;  $Z = 5.420$ ; T-value = 5.418; and p-value  $< 0.0001$ ).

*Table 8:5: Constructs' Model Fit Result*

ONE-FACTOR MODELS FIT RESULT						
MODEL FIT METRICS	Recommended	BEP Single-factor	Operational	Mgt_Policy	Strat_Drivers	Acceptability
Normalised Chi-Square (CMIN/DF)	$< 3$	0.751	6.962	0.001	0.396	Poor
P-Value for the Model	$> .05$	0.522	0.008	0.980	0.852	Good
RMR (Root-Mean-Square- Residual)	$< .05$	0.011	0.217	0.001	0.004	Good
CFI (Comparative Fit Index)	$> .95$	1.000	0.971	1.000	1.000	Good
GFI (Goodness of Fit)	$> .95$	0.994	0.963	1.000	0.994	Good
AGFI (adjusted Goodness of Fit Index)	$> .95$	0.955	0.776	1.000	0.981	Good
PGFI	$> .50$	0.142	-	0.167	0.330	Poor
RMSEA	$< .05$	0.000	0.224	0.000	0.000	Good
PCLOSE	$> .05$	0.637	0.019	0.983	0.915	Good
NFI (Normed Fit Index)	$> .92$	0.994	0.967	1.000	0.995	Good
RFI (Relative Fit Index)	$> .90$	0.972	0.900	1.000	0.991	Good
IFI (Increment Fit Index)	$> .90$	1.002	0.971	1.005	1.007	Good
TLI (Trucker Lewis Index)	close to 1.00	1.01	0.913	1.016	1.014	Good
PRATIO	Value $> .60$	0.200	0.333	0.333	0.500	Poor
PCFI	Value $> .60$	0.200	0.322	0.333	0.498	Poor
Standardised RMR	Value $< 0.08$	0.018	0.040	0.000	0.010	Good
Bollen-Stine Bootstrap	Value $> .50$	0.617	0.080	0.960	0.960	Good

The management policy construct model (Figure 8.3), manifested a good fit without any form of modification. Result (Table 8:5), reveals acceptable ( $\chi^2(1) = 0.001$ ; CMIN/DF = 0.001; p-value = 0.980; RMSEA = 0.000 and PCLOSE = 0.983) at significance level. Also, its Bollen-Stine bootstrap value (p = 0.960), and standardised RMR (0.003) shows acceptable overall independent sub-model that equally fit collected data.

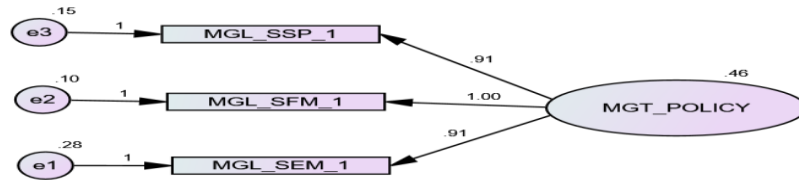


Figure 8.3: Management Policy Construct Model

All regression coefficient and coefficient of determination for its indicators have z-values > than 1.96, and significance at p-value < than 0.0001). Similarly, the constructs' path correlation coefficient indicates the three paths: managerial to MGL\_SEM ( $\beta = 0.527$ ); MGL\_SFM ( $\beta = 0.527$ ); and MGL\_SSP ( $\beta = 0.760$ ), have high coefficient of determinations with same Z= 11.908; and T-value= 11.961 at p-value < 0.0001 level of significance.

The Operational solution construct-model is also specified (Figure 8.4). The result (Table 8:5), also reveals acceptable independent fit indices. Its model indices without modification ( $\chi^2(1) = 6.962$ ; CMIN/DF= 6.962; p-value= 0.008; RMSEA= 0.224 and PCLOSE= 0.019), shows poor fit at non-significance level. Besides, its Bollen-Stine bootstrap value (p= 0.080) is poor, and standardised RMR (0.040) shows acceptable overall independent sub-model. It also indicates model can be improved upon.

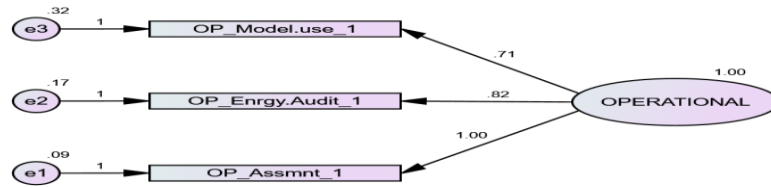


Figure 8.4: Operational Construct Model

It is observed that this construct has poor fit compared to other construct models with good fit. This is because of the removal of HVAC indicator from this construct due to its low communalities. This indicator improved operation sub model fits (to  $\chi^2(5) = 1.979$ ; CMIN/DF= 0.396; p-value= 0.852; RMSEA= 0.000 and PCLOSE= 0.915).

The CFA revealed that, HVAC weakens the overall measurement and structural models by causing low factor loadings for the SBM indicators. Theoretically, HVAC matching is not a procedure (like energy audit and assessment or use of model, which are processes with definite protocol), but rather a technique of reducing energy waste. This could be the plausible reason for its low factor loading in the general model that justified its removal.

Construct regression coefficient and coefficient of determination for its indicators have z-values  $> 1.96$ , and significance at p-values  $< 0.0001$ . Its path correlation coefficient indicates that operational to: OP\_Assmnt ( $\beta = 0.960$ ); OP\_Energy-Audit ( $\beta = 0.895$ ; Z-value= 15.603; t-value= 15.603); and OP\_Model use ( $\beta = 0.714$ ; Z-value= 11.827; t-value= 11.900), all have high coefficient of determinations at p-value  $< 0.001$  level of significance.

The fourth sub-model (strategic drivers' construct) indicates (Table 8:5), the best fit without initial modification amongst others (Figure 8.5). Its result ( $\chi^2(5) = 1.979$ ; CMIN/DF= 0.396; p-value= 0.852; RMSEA= 0.000 and PCLOSE= 0.925) is acceptable at significance level.

While construct's Bollen-Stine bootstrap value ( $p = 0.960$ ) and standardised RMR (0.010) displays good overall independent sub-model that indicates model fit data.

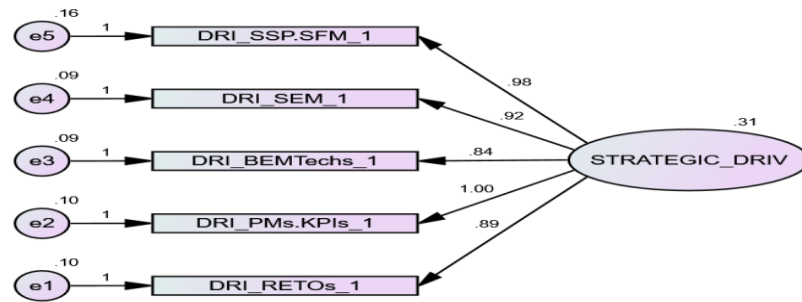


Figure 8.5: Drivers Construct Model

Its regression coefficient and coefficient of determination also indicate z-values  $> 1.96$ , and significance at p-values  $< 0.0001$ . The path correlation coefficients from drivers to: Dri\_RETOs ( $\beta = 0.837$ ; Z-value= 11.733; t-value= 11.671); Dri\_PMs-KPIs ( $\beta = 0.866$  constrained); Dri\_BEMTechs ( $\beta = 0.844$ ; Z-value= 11.889; t-value= 11.845); Dri\_SEM ( $\beta = 0.865$ ; Z-value= 12.425; t-value= 12.459); and Dri\_SSP-SFM ( $\beta = 0.800$ ; Z-value= 10.878; t-value= 10.878), have high coefficient of determinations at p-value  $< 0.001$  level of significance.

## II. Measurement Model

The study applied Chi-square test; the absolute fit (baseline fit measures); incremental fit indices; and parsimonious fit indices (Yoon, Gursoy and Chen, 2001; Blunch, 2008) as indices for judging model fits. Model fit criteria is used for current models instead of  $\chi^2$ -test criteria, due to study relatively moderate size; and the fact that  $\chi^2$ -test is dependence on sample size (Blunch, 2008).

Measurement model initial fit result (Table 8:6), reveals a recursive model, meaning its dependent latent variables can predict another. The theoretical model fit index indicates initial normalised chi-square value (CMIN/DF= 2.035) with p-value (0.000) < 0.05 significance level. Other model fit indices result: RMR (0.052), PGFI (0.640), and CFI (0.905), indicate adequacy. However, it initial  $\chi^2$  (31) = 2.035, though significant nevertheless, is identified and could be improved upon.

Modification is performed by inter-correlation of some error terms of the reflective indicators without theoretical complication to the model (Gaskin, 2012). The Amos 23 modification indices is used as guide by adding covariance between these error terms (covaried): BEP (e1-e4; e2- e6; e3- e6; e4- e5; e4- e6; and e5- e6), managerial (e12- e13), and operational (e15- e16). Theoretically, current study has established associations between the covaried variables.

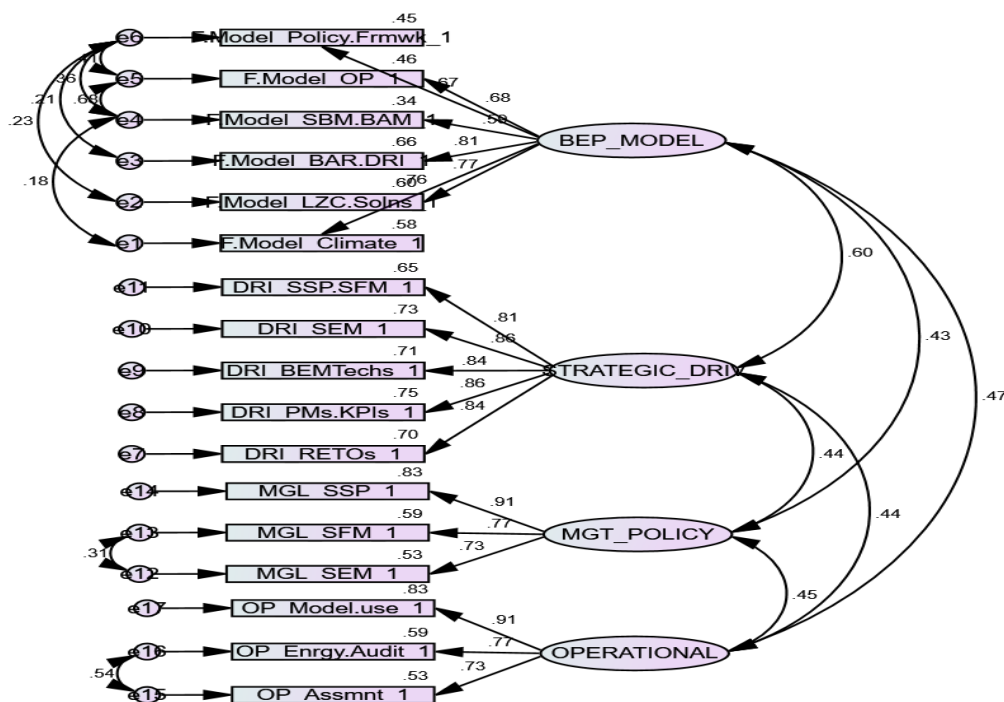


Figure 8.6: 4-Factor Measurement SBM Model for Improving BEP.

The new improved model (Figure 8.6), reveals good overall model fit on the four fit criteria compared to the initial model result (Table 8:6). The normalised chi-square ( $\chi^2$ ) (39) = 1.455,  $p = 0.001 < 0.05$  is still significant, nonetheless, it indicates a good fit when compared against



benchmark ( $< 3$ ). The root-mean-squared residual ( $\text{RMR} = 0.046 < 0.05$ ), is excellent, and goodness-of-fit index ( $\text{GFI} = 0.869$ ) is within acceptable level of fit.

*Table 8:6: 4-Factor Measurement SBM Model Fit Result.*

4-FACTOR MEASUREMENT MODEL FIT RESULT				
MODEL FIT METRICS	Theoretical model	New 4-Factor Model-MM	Recommended	Acceptability
Normalised Chi-Square (CMIN/DF)	2.005	1.455	$< 3$	Good
P-Value for the Model	0.000	0.001	$> .05$	Acceptable
RMR (Root-Mean-Square- Residual)	0.056	0.046	$< .05$	Good
CFI (Comparative Fit Index)	0.905	0.961	$> .95$	Good
GFI (Goodness of Fit)	0.806	0.869	$> .95$	Acceptable
AGFI (Adjusted Goodness of Fit)	0.74	0.824	$> .95$	Acceptable
PGFI	0.601	0.648	$> .50$	Good
RMSEA	0.096	0.062	$< .05$	Acceptable
PCLOSE	0.000	0.171	$> .05$	Good
NFI (Normed Fit Index)	0.837	0.887	$> .92$	No
RFI (Relative Fit Index)	0.805	0.865	$> .90$	No
IFI (Increment Fit Index)	0.907	0.962	$> .90$	Good
TLI (Trucker Lewis Index)	0.887	0.954	Close to 1.00	Good
PRATIO	0.838	0.838	Value $> .60$	Good
PCFI	0.759	0.806	Value $> .60$	Good
Standardised RMR	0.079	0.074	value $< .08$	Good
Bollen-Stine Bootstrap	0.358	0.791	Value $> .50$	Good

Whilst, comparative fit index: CFI (.961), IFI (.962), and TLI (.954) indicates good model fit. Also, the root-mean-squared-error-of-appropriation ( $\text{RMSEA} = 0.065$ ) with  $p = 0.171$  is demonstrating good model fit. Finally, the parsimonious fit measures: PRATIO (0.838), PNFI (0.744), and PCFI (0.806), all indicates excellent fit result above the recommended level (0.600).

Overall model fit result (Bollen-Stine,  $p\text{-value} = 0.791 > 0.100$ ; and Standardised  $\text{RMR} = 0.074 < 0.080$ ), proves the prior model reproduces same data; it indicated that the data fit prior theoretical knowledge. Also, when current model is nested with a baseline model it compared favourably well with independent model.

The result (Table 8:7 and Table 8:8), establishes that all endogenous (observed) variables have high standardised loadings on respective exogenous variables. Examining their Z-values associated with loadings, it indicates all path critical ratio (C.R.) (Z-values), are higher than 1.95 (minimum) C.R. (Hui, 2011). Likewise, all estimated paths are positive and significant at  $p\text{-values} < 0.000$ . Operational to OP\_Model use and managerial to MGL\_SSP, have the highest standardised loadings ( $\beta = 0.910$ ; C.R. = 9.860;  $t\text{-value} = 9.890$ ). Whilst, the lowest loading is recorded in the path between final model SBM for BAM and BEP model ( $\beta = .587$ ; C.R. = 6.66;  $t\text{-value} = 6.640$ ). The result indicates a reliable measurement for data and internal consistency of measured variables.

Table 8:7:4-Factor Measurement Model Result.

OVERALL CFA FOR 4-FACTOR MEASUREMENT MODEL (N=120)					
FACTORS AND INDICATORS	Standardised Loading	Factor Loadings (> .70)	Constructs and Indicators Reliability	Average Variance Extracted (>.50) and Error Variance	R-Square (Squared Multiple Correlation)
<b>BEP Model for Improving</b>			0.881	0.543	
Model_Policy Framework	0.671	0.866			0.450
Model_Operational Framework	0.681	0.774			0.464
Model_SBM-BAM	0.587	0.747			0.345
Model_Barrier and Driver	0.812	0.743			0.659
Model_LZC. Solns.	0.773	0.663			0.598
Model_Climate	0.759	0.627			0.576
<b>Strategic Drivers</b>			0.924	0.686	
Dri_Strategic Energy Mgt (SEM)	0.856	0.936			0.734
Dri_BEMTechs.	0.841	0.846			0.707
Dri_PMs.KPIs	0.865	0.842			0.748
Dri_RETOs	0.835	0.784			0.698
Dri_Embedded SSP & SFM	0.809	0.733			0.654
<b>Operational Solution</b>			0.882	0.669	
Op_Regular Assessment (Assmnt)	0.730	0.977			0.532
Op_Energy Audit	0.766	0.821			0.586
Op_Model Use	0.920	0.657			0.827
<b>Management Policy</b>			0.875	0.663	
Mgl_SFM	0.766	0.954			0.586
Mgl_SSP	0.910	0.752			0.827
Mgl_SEM	0.730	0.737			0.532

Table 8:8: 4-Factor MM Paths' Estimations.

4-Factor Measurement (MM) Model Regression Estimations						
			Estimate	S.E.	C.R.	P Label
F.Model_Climate_1	<---	BEP_MODEL	1.000			
F.Model_LZC.Solns_1	<---	BEP_MODEL	0.939	0.113	8.33	*** W1
F.Model_BAR.DRI_1	<---	BEP_MODEL	0.868	0.099	8.73	*** W2
F.Model_SBM.BAM_1	<---	BEP_MODEL	0.664	0.1	6.663	*** W3
F.Model_OP_1	<---	BEP_MODEL	0.781	0.107	7.27	*** W4
F.Model_Policy.Frmwk_1	<---	BEP_MODEL	0.894	0.132	6.792	*** W5
DRI_RETOs_1	<---	STRATEGIC_DRIV	1.000			
DRI_PMs.KPIs_1	<---	STRATEGIC_DRIV	1.143	0.096	11.949	*** W6
DRI_BEMTechs_1	<---	STRATEGIC_DRIV	0.959	0.084	11.409	*** W7
DRI_SEM_1	<---	STRATEGIC_DRIV	1.045	0.089	11.759	*** W8
DRI_SSP.SFM_1	<---	STRATEGIC_DRIV	1.133	0.106	10.725	*** W9
MGL_SEM_1	<---	MGT_POLICY	1.000			
MGL_SFM_1	<---	MGT_POLICY	0.973	0.063	15.357	*** W10
MGL_SSP_1	<---	MGT_POLICY	1.167	0.118	9.86	*** W11
OP_Assmnt_1	<---	OPERATIONAL	1.000			
OP_Engry.Audit_1	<---	OPERATIONAL	0.973	0.063	15.357	*** W10
OP_Model.use_1	<---	OPERATIONAL	1.167	0.118	9.86	*** W11

### 8.7.3 Reliability Test

Result (Table 8:7), indicates high reliability for construct and indicators based on Cronbach's alpha reliability (BEP  $\alpha = 0.881$ ; Strategy  $\alpha = 0.924$ ; operational  $\alpha = 0.882$ ; and policy  $\alpha = 0.875$ ),  $\alpha$ -values > than 0.70 (Nunnally and Bernstein, 1994). The factors under each construct are highly correlated that support their use, and indicates reflective and interchangeable indicators (Gaskin, 2012).

#### 8.7.4 Validity Test

Validity test is used for model identification through convergent and discriminant validities. CFA result confirmed that the measurement model is adequately identified as thus:

##### *I. Convergent Validity*

Result (Table 8:9), indicates study constructs does not have any convergent issues. Their average variances extracted (AVE) and composite reliabilities (CR), indicates high convergent of variables under each construct. Constructs' AVE (BEP = 0.513; Strategic\_DRIV = 0.676; OP = 0.680; and Mgt\_Policy = 0.680) are > than the acceptable threshold  $\geq 0.500$  (Hair, Ringle and Sarterdt, 2011).

*Table 8:9: Convergent Validity: Measurement Model*

CONVERGENT VALIDITY: MEASUREMENT MODEL				
Convergent Validity	BEP	STRAT_DRIV	OPL	POLICY
AVE (R2)= formula (); Value > .500	0.513	0.676	0.680	0.680
Composite Reliability (CR)= FL; Value > .700	0.715	0.822	0.820	0.820
Convergent Validity	Established	Established	Established	Established

Table adapted from: Math Zero (Math, 2015).

The constructs have high and common factor loading of  $0.820 <$  than the 0.700 recommended threshold. Convergent is established in current model as indicated in the result; and each factor's indicator measured the same construct (Hair et al., 2010).

##### *II. Discriminant Validity*

Discriminant validity is checked for cross-loading; and it result (Table 8:10), reveals that all constructs are measuring different things.

*Table 8:10: Discriminant Validity: Measurement Model*

DISCRIMINANT VALIDITY: MEASUREMENT MODEL				
Discriminant Validity	Factor Correlation	Correlation Squared	AVE 1: AVE 2; (AVEs > r2)	Discriminant Validity
BEP- STRAT_DRIV	0.596	0.355	0.513: 0.676	Established
STRAT_DRIV - MGL_POLICY	0.442	0.195	0.676: 0.680	Established
BEP- MGL_POLICY	0.426	0.181	0.513: 0.680	Established
BEP - OPERATIONAL	0.473	0.224	0.513: 0.680	Established
STRAT_DRIV - OPERATIONAL	0.442	0.195	0.676: 0.680	Established
MGL_POLICY - OPERATIONAL	0.454	0.206	0.680: 0.680	Established

Table adapted from Math Zero (Math, 2015).

There is no issue of cross loadings, as the values of correlation squared amongst constructs are lower than the AVE for each construct. Therefore, discriminant validity is established in current model (Gaskin, 2012; Math, 2015).

#### 8.7.5 Metric Invariance Test

Results from the standardised root mean residual (SRMR) indicated (Table 8:6), shows the construct and measurement models have good configured variances. Individual SRMR is < .100 threshold (Byrne, 2010) as thus: BEP construct (0.0184), operational construct (0.0399), management policy construct (0.003), strategic drivers construct (0.0096), and measurement model (0.0736).

#### 8.7.6 Nomological test.

Overall fitness of study models to data collected is also examined. The Bollen-Stine bootstrap (Bollen and Stine, 1993), and the standardised root mean residual (SRMR), are utilised for testing the overall validity of null hypothesis. It confirms the ability of the test of the null hypothesis in proving that the model is correct.

The closer the Bollen-Stine's p-value to 1.00 absolute value, the better fit the overall model fit for the hypothesis. Whilst, the lower the SRMR's p-value  $\leq$  than 0.080 (Schreiber, 2008), the better fit the overall model. The newly improved measurement model (MM) indicates a Bollen-Stine p-value of 0.791 > than 0.500; and SRMR p-value of 0.074 < than 0.080, confirming that overall model fit well collected data.

### 8.8 STRUCTURAL MODEL FITTING AND EVALUATION

The relationship amongst the four latent constructs is investigated based on study hypothesis that significant causal relationship exists between constructs. The constructs are the single-factor BEP model for BEP and the constructs of strategic drivers, managerial policy and operational solutions. A four-path initial structural model-1 (Figure 8.7), is created to represent the causal relationships (Ko and Stewart, 2002) and evaluate them. The objective is to know how much each constructs and respective variables explain the performance of the BEP model in improving BEP; and test study hypotheses.

The first hypothesised path is the relationship between construct of management policy and strategic drivers (H1). The second path is that of strategic drivers and BEP sub-model (H2) affiliation. The third path is the link between BEP sub-model and operational solutions (H3). While fourth path is the connection between constructs of operational solutions and management policy (H4). Additionally, a second structural model-3 is created by reversal of the directional arrow in path H4 as solution model-3 labelled H5 based on the theoretical model.

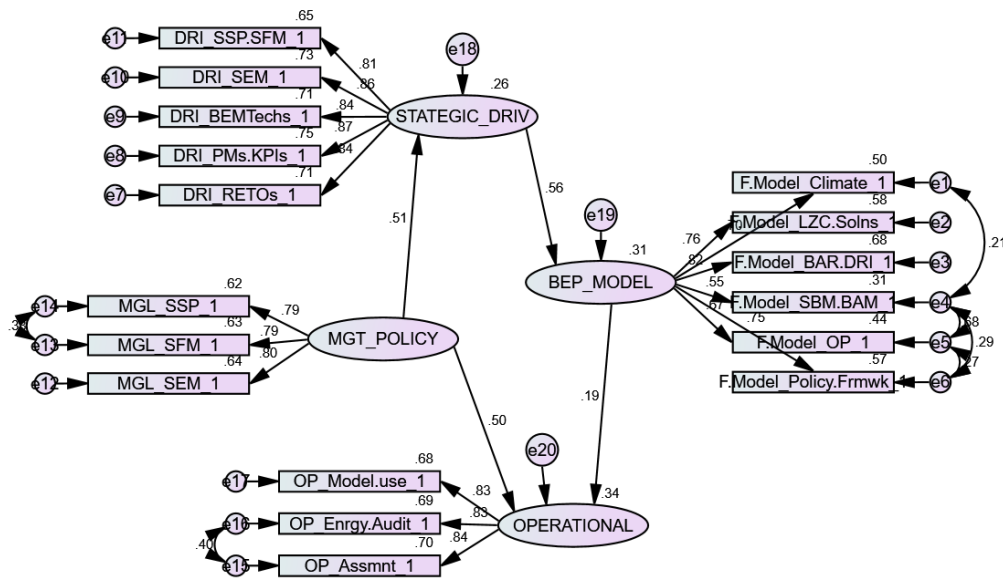


Figure 8.7: Initial Structural Model-1

Review of the measurement model indicates good model fit indices with t-value of all standardised coefficient being significance. Nevertheless, its chi-square value is not-significant, indicative of the measurement model being under-identified and could be improved upon. Hence, the evaluation of structural connection between the four constructs is important in achieving study objectives.

### 8.8.1 Model Fits

The result of the initial structural model-1 (Figure 8.7), indicates a good fitted model except for its chi-square ( $\chi^2$  (120) = 164.599) that is significant at p-value (0.004) < than 0.05 level. Most of the model t-values for completely  $\beta$ -coefficients are also statistically significant. The lone exclusion is that of the association between BEP and operational solution (H3,  $\beta \approx 0.186$ ; p-value = 0.064), which > than 0.05 level of significance.

Model covariance and variances are positive and significant at 0.001 level; and most its standardised residual values are < than 2.0 absolute values, which mean the model-1 is correct. The path correlation coefficient and its determinations (Table 8:11), indicates model z-values are outside the threshold of 1.96 C.R. It also reveals that all variables have their SDs above their means.

Table 8:11: Initial Structural Model-1 Regression Estimates

Initial Structural Model-1 Regression Estimates								
		Constructs	Unstandardised	Standardised	S.E.	C.R.	P	T-value
Strategic_Dri	<-	Mgt_Policy	0.439	0.512	0.086	5.074	***	5.105
BEP_Model	<-	Strategic_Dri	0.629	0.557	0.105	5.961	***	5.990
Operational	<-	Mgt_Policy	0.57	0.502	0.118	4.838	***	4.831
Operational	<-	BEP_Model	0.218	0.186	0.117	1.853	0.064	1.863
F.Model_Climate_1	<-	BEP_Model	0.914	0.705	0.088	10.412	***	10.386
F.Model_LZC.Solns_1	<-	BEP_Model	0.914	0.763	0.088	10.412	***	10.386
F.Model_BAR.DRI_1	<-	BEP_Model	0.883	0.823	0.06	14.7	***	14.717
F.Model_SBM.BAM_1	<-	BEP_Model	0.629	0.554	0.093	6.773	***	6.763
F.Model_OP_1	<-	BEP_Model	0.766	0.666	0.089	8.563	***	8.607
F.Model_Policy.Frmwk_1	<-	BEP_Model	1	0.753				
DRI_RETOS_1	<-	Strategic_Dri	0.883	0.841	0.06	14.7	***	14.717
DRI_PMs.KPIs_1	<-	Strategic_Dri	1	0.867				
DRI_BEMTechs_1	<-	Strategic_Dri	0.835	0.842	0.068	12.362	***	12.279
DRI_SEM_1	<-	Strategic_Dri	0.908	0.856	0.071	12.772	***	12.789
DRI_SSP.SFM_1	<-	Strategic_Dri	0.984	0.808	0.086	11.465	***	11.442
MGL_SEM_1	<-	Mgt_Policy	1	0.801				
MGL_SFM_1	<-	Mgt_Policy	0.92	0.794	0.062	14.914	***	14.839
MGL_SSP_1	<-	Mgt_Policy	0.914	0.79	0.075	12.172	***	12.187
OP_Assmnt_1	<-	Operational	1	0.836				
OP_Engy.Audit_1	<-	Operational	0.92	0.829	0.062	14.914	***	14.839
OP_Model.use_1	<-	Operational	0.914	0.825	0.075	12.172	***	12.187

Model-1 paths' coefficient indicated the following percent variances for its structure: H1 accounts for about 51.0% of the total variances of the relationship between management policy and strategic drivers construct; path H2 accounts for 56.0%; path H3 accounts for 19.0%; and path H4 accounts for 50.0% between its constructs. Individual construct: strategy (26.2%), BEP (31.0%), operations (34.0%), and policy (42.0%), have a reasonable percentage of the entire

model variance. Whilst, the model-1 explained 67.3% of the variance of the whole BEP model for BEP.

Evaluation of the models' fit reveals that there is no significant difference between MM-model ( $\chi^2$  (114) = 165.895; p-value= 0.001) and initial structural model-1 ( $\chi^2$  (117) = 154.832; p-value= 0.011). It indicates that structural model-1 is a parsimonious model of the MM-model at  $\Delta p$ -value < 0.01;  $\Delta\chi^2$  (6) = 11.063 difference that is not significant. Hence the structural model-1 is adopted as the better model to test the study hypotheses (Yoon, Gursoy and Chen, 2001).

Table 8:12: SEQM Models Result.

SEM MODEL FIT RESULTS					
MODEL FIT METRICS	Structural Model-1	Diagnostic Model-2	Solution Model-3	Recommended	Acceptability
Chi-Square X2	154.832	126.892	127.247	Nil	
DF (Degree of Freedom)	117	114	111	> 1.0	Good
Chi-Square/DF (CMIN/DF)	1.323	1.143	1.146	< 3.0	Good
P-Value for the Model	0.011	0.144	0.139	> .05	Good
RMR (Root-Mean-Square- Residual)	0.034	0.032	0.031	< .05	Good
CFI (Comparative Fit Index)	0.972	0.988	0.988	> .95	Good
GFI (Goodness of Fit)	0.876	0.893	0.892	> .95	Acceptable
AGFI (Adjusted Goodness of Fit)	0.837	0.852	0.851	> .95	Acceptable
PGFI	0.670	0.648	0.647	> .50	Good
RMSEA	0.052	0.035	0.035	< .05	Good
PCLOSE	0.422	0.817	0.812	> .05	Good
NFI (Normed Fit Index)	0.895	0.914	0.913	> .92	Acceptable
RFI (Relative Fit Index)	0.877	0.894	0.894	> .90	Acceptable
IFI (Increment Fit Index)	0.972	0.988	0.988	> .90	Good
TLI (Trucker Lewis Index)	0.967	0.985	0.985	close to 1.00	Good
PRATIO	0.86	0.816	0.816	Values > .60	Good
PCFI	0.836	0.806	0.806	Values > .60	Good
SRMR	0.063	0.069	0.058	Values < .08	Good
Bollen-Stine Bootstrap	0.896	0.945	0.945	> .50 < 1.0	Good

There is significant improvement on the initial structural model-1 compared to the measurement model. Although, model-1  $\chi^2$  (117) = 154.832 is not significant, other fit indices (Table 8:12), indicate that the model is satisfactory: CMIN/DF=1.323; p-value= 0.011; RMSR= 0.034; CFI= 0.972; GFI= 0.876; RMSEA= 0.052; PCLOSE= 0.422; IFI= 0.972; PCFI= 0.836; SRMR= 0.063; and Bollen-Stine p= 0.896.

### I. Diagnostic model

The maximum modification index is used in improving the structural model-1 to two proposed new models since, the chi-square statistics and other fit indices are not highly acceptable. The following error terms (Figure 8.8), are further covaried for new paths: from Dri\_SSP-SFM (e11) to F.Model\_Climate (e1); e11 to F.model\_LZC (e2); and e11 to F.Model\_BAR.DRI (e3). Also, from MGL\_SFM (e13) to Dri-RETOs (e7); and to DRI\_PMs.KPIs (e8). The first new model is a diagnostic model-2. It has flow process that sets out from management policy via



strategy to BEP sub-model, while also impacting daily operations; and the remainder of the operational phase as a feedback loop.

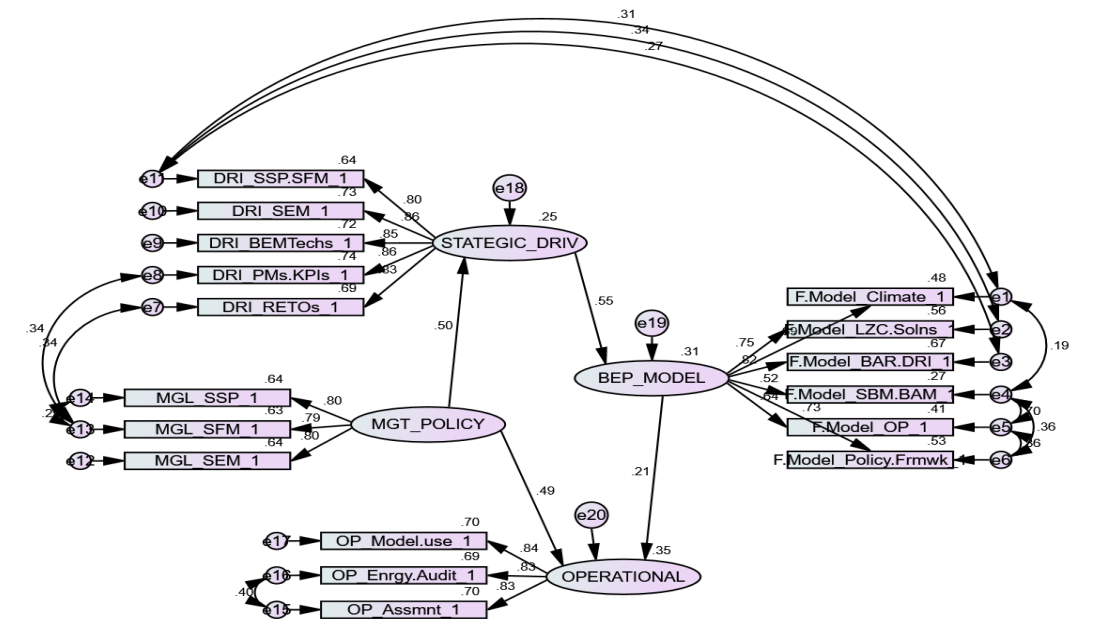


Figure 8.8: Diagnostic Phase Model-2

Model fit evaluation of the new structural model-2 indicates an acceptable fit index for all model fit statistics (Table 8:12). There is a significant difference between model-1 and the new model-2 (diagnostic) with a decrease in chi-square statistics ( $\chi^2$  (114) = 126.892; p-value = 0.114). The differences between initial model-1 and the new diagnostic model-2 is very significant ( $\Delta\chi^2$  (3) = 27.940;  $\Delta DF$  = 3,  $\Delta p$ -value = 0.133). Also, its Bollen-Stine bootstrap ( $\Delta p$ -value = 0.945 > than 0.896); and standardised RMR  $\Delta$  = 0.063 < than 0.069), which indicates acceptable overall hypothesised model. Hence, the diagnostic model-2 is accepted as an improved model and best for testing the hypotheses.

Other fit indices are (Table 8:12) are within the acceptable threshold of a good model fit as thus: CMIN/DF=1.143; p-value= 0.144; RMR= 0.032; GFI= 0.893; PGFI= 0.648; CFI= 0.988; RMSEA= 0.035; Pclose= 0.817; IFI= 0.998; and PCFI= 0.806. Structurally, management policy construct accounts for the largest share (41.0%) of the variances of the entire diagnostic model-2 process. Also, BEP sub-model (31.0%), operations (35.0%), and drivers (25.0%) accounts for a significant share of the model-2 divisions.

## II. Solution model



A new model-3 is also created that supplies a feedback mechanism from diagnostic phase to solution implementation phase. This is achieved by reverting the path H4 (in model-2), to become H5 (in model-3).

It is observed that the path coefficient for operational and BEP sub-model construct though the weakest but is significant ( $\alpha = 0.257$ ;  $z\text{-value} = 2.175$ ;  $p\text{-value} = 0.030$ ) in model-2. But becomes stronger ( $\alpha = 0.296$ ;  $z\text{-value} = 2.174$ ;  $p\text{-value} = 0.030$ ) in model-3. The plausible reason is that the BEP model is also feeding operational sub model, the results of implemented solutions. Also, the BEP is wider and most effective tool for dealing with BEP issues than the traditional operational (energy audit and assessment) tool. Hence, the more effective use of the BEP model in improving BEP, the lesser the use of traditional operational tools for the same purpose.

In order, not to alter the structure of the structural model, the path correlation coefficient for the constructs of management policy  $\rightarrow$  operational is reversed (from operational  $\rightarrow$  management policy: H5). This shaped the new solution phase model-3 for testing hypotheses (Figure 8.9).

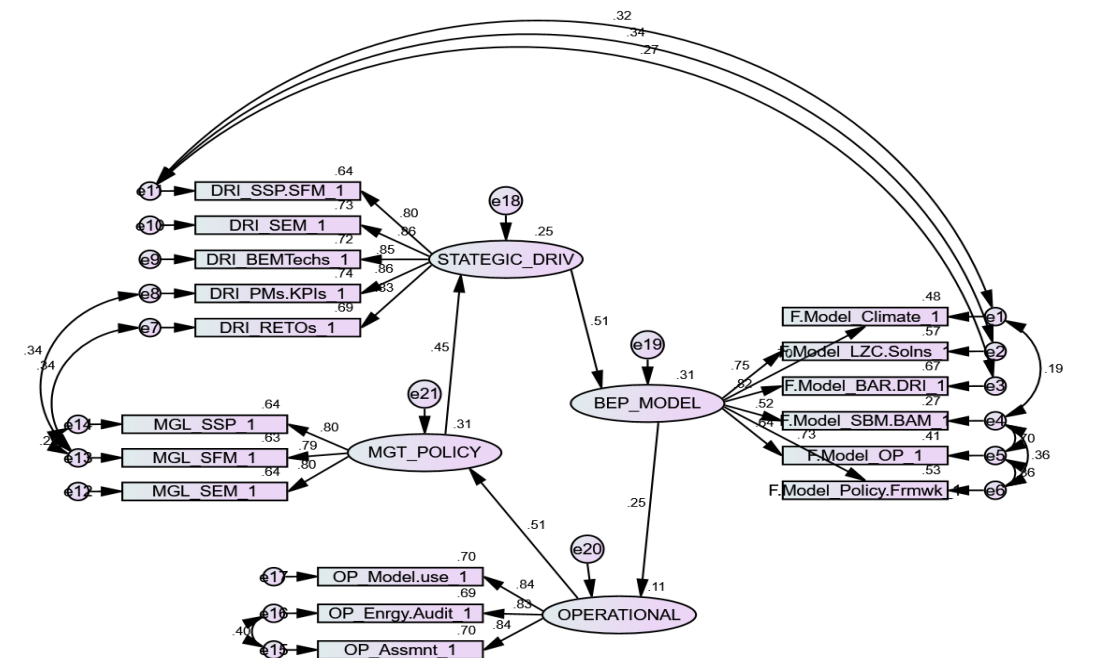


Figure 8.9: Solution Phase Model-3

The resultant model-3 is also good and not significantly different from model-2, as both have almost the same acceptable fit indices (Table 8:12). Its chi-square statistics ( $\chi^2 (111) = 127.247$ ;

p-value = 0.139) is significant. While others: CMIN/DF=1.146; RMR= 0.031; GFI= 0.892; PGFI= 0.647; CFI= 0.988; RMSEA= 0.035; Pclose= 0.812; IFI= 0.988; and PCFI= 0.806 also indicates good fit. However, the BEP sub-model (31.0%) and management policy (31.0%) now have the largest share of the variances of the structural solution model-3 process. The strategic drivers construct (25.0%) and operational (11.0%), also accounts for substantial shares. Operational share of model-3 variances is the least because of its role taken over by the BEP sub model.

Structurally, the constructs had the bulk of the share variances of the entire model compared to variations due to their error terms (2.0%). This implies that the entire solution model will account for the majority (about 98.0%) of identified critical factors that affects BEP than other unknown factors due to chance (about 2.0%).

### 8.8.2 Model Evaluation: Composite from Factor Scores

The structural models (2 & 3) are further evaluated based on composite scales from factor scores as validation. New average variables from model's variables are created using IBM SPSS 22. The new data is applied to produce the two new composite scale models based on study structural model-2 and model-3 via IBM AMOS 23. The models' structures are assessed for convergent validity for testing study hypotheses.

The result (Table 8:13) for the four constructs shows all constructs that made up the composite models established convergent validity. Constructs' convergent reliability (CR) is deduced from the averages of standardised regression estimate ( $\beta$ ) of all the reflective indicators under each construct.

Table 8:13: Convergent Validity: Composite Scale Model

Convergent Validity: Composite Scale Model				
Convergent Validity	BEP	STRAT_DRI	OPERATIONAL	MGL_POLICY
CR	0.715	0.822	0.820	0.820
Factor Loading= square root of CR	0.846	0.907	0.906	0.906
Error Variance= 1-CR	0.285	0.178	0.180	0.180

The established convergent reliability reveals that all reflective indicators under each factor are measuring the same thing. The model fit indices for each composite scale model (Table 8:14), were further evaluated as follows:

Table 8:14: Composite Scale Models' Fit Result.

Composite Scale Model Fit Results				
MODEL FIT METRICS	Diagnostic Model-2a	Solution Model-3a	Recommended	Acceptability
Chi-Square X2	2.099	2.114	Nil	Good
DF (Degree of Freedom)	2	2	> 1.0	Good
Chi-Square/DF (CMIN/DF)	1.049	1.057	< 3.0	Good
P-Value for the Model	0.350	0.348	> .05	Good
RMR (Root-Mean-Square- Residual)	0.009	0.009	< .05	Good
CFI (Comparative Fit Index)	0.999	0.999	> .95	Good
GFI (Goodness of Fit)	0.992	0.991	> .95	Good
AGFI (Adjusted Goodness of Fit)	0.958	0.957	> .95	Good
PGFI	0.198	0.198	> .50	Poor
RMSEA	0.020	0.022	< .05	Good
PCLOSE	0.452	0.449	> .05	Good
NFI (Normed Fit Index)	0.978	0.978	> .92	Good
RFI (Relative Fit Index)	0.933	0.933	> .90	Good
IFI (Increment Fit Index)	0.999	0.999	> .90	Good
TLI (Trucker Lewis Index)	0.997	0.996	close to 1.00	Good
PRATIO	0.333	0.333	Values > .60	Poor
PCFI	0.326	0.326	Values > .60	Poor
SRMR	0.024	0.023	Values < .08	Good
Bollen-Stine Bootstrap	0.662	0.662	> .50 < 1.0	Good

The unstandardized coefficient (Table 8:15), is used in assessing the significance of models' causal paths for hypothesis testing.

Table 8:15: Composite Scale Structural Model-2a & 3a: Regression Estimates

Composite Scale Structural Model-2a: Diagnostic Phase- Regression Estimates								
		Unstandardised	Standardised	S.E.	C.R.	T-value	P	Label
Strat_Driv	← Mgt_Policy	0.492	0.634	0.11	4.487	4.473	***	H1 +
BEP_Model	← Strat_Driv	1.013	0.807	0.172	5.885	5.890	***	H2 +
Operational	← Mgt_Policy	0.807	0.688	0.209	3.866	3.861	***	H4 +
Operational	← BEP_Model	0.042	0.035	0.197	0.211	0.213	0.833	H3 -
Composite Scale Structural Model-3a: Solution Phase- Regression Estimates								
		Unstandardised	Standardised	S.E.	C.R.	T-value	P	Label
Mgt_Policy	← Operational	0.621	0.732	0.144	4.319	4.313	***	H5 +
Strat_Driv	← Mgt_Policy	0.52	0.668	0.165	3.15	3.152	0.002	H1 +
BEP_Model	← Strat_Driv	1.031	0.82	0.199	5.175	5.181	***	H2 +
Operational	← BEP_Model	-0.068	-0.056	0.404	-0.168	-0.168	0.867	H3 -

#### I. Composite Scale: Diagnostic Phase Model-2a

Model fit result (Table 8:14) for the composite scale model-2a indicates (Figure 8.10) that the chi-square ( $\chi^2$ ) (2) = 2.099; p-value= 0.35 > 0.05; and the REMSEA= 0.020 < 0.05; Pclose= 0.452 > 0.05 are significant. Also, other fit indices: CMIN/DF= 1.049; RMR= 0.009; GFI= 0.992; AGFI= 0.958; CFI= 0.999; NFI= 0.927; IFI= 0.947; and SRMR= 0.024, improved indicating a good model fit. Thus, the overall model is acceptable as well, and it confirmed diagnostic model-2 as the best hypothesised model.

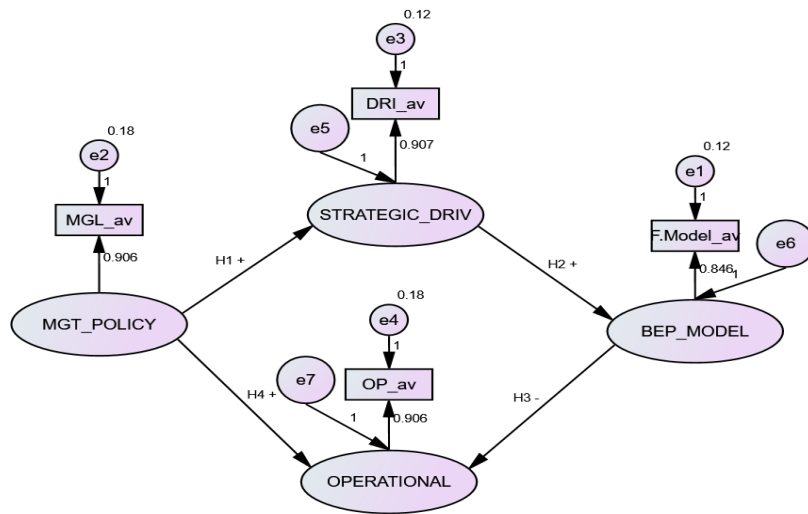


Figure 8.10: Composite Scale Model: Diagnostic Model-2a.

The causal path coefficient ( $\alpha = \alpha$ ) of model-2a was likewise examined for significance using the unstandardized coefficient (table 9.15 above). It is observed that one out of four of the causal paths, H3 ( $\alpha = 0.042$ ;  $z = 0.211$ ;  $p = 0.833 > 0.05$ ), is not significant. Others regression weights'  $\alpha$ - values: H1 ( $\alpha = 0.492$ ;  $z = 4.487$ ); H2 ( $\alpha = 1.013$ ;  $z = 5.885$ ); and H4 ( $\alpha = 0.807$ ;  $z = 3.866$ ), are significant at  $p$ -values  $<$  than 0.001% significance level. The absolute values for all factors standardised residual covariance are  $<$  than 2.0.

The BEP model error term (e6) indicates a negative (-15), which also affirmed that the input matrix lack sufficient information. This is corrected by imposition of equality constraints between the largest parameters error terms e1 and e3 (Byrne, 2010). It improved the composite model greatly with error e6 changed to +11. Consequently, the model is good for testing the causal relationship between the constructs. The model is accurate at examining the causal effects between study construct and be applied to the general population or larger sample size. Besides, I could conclude that the model is not a 100% complete, hence the need to check for mediating effects.

## II. Composite Scale: Solution Phase Model-3a

Structural model-3 is also evaluated via its composite scale model-3a (Figure 8.11). The Model-3a result indicates good fit and no significant difference with model-2a. Its chi-square ( $\chi^2$ ) (2) = 2.114; p-value= 0.348 > 0.05; and REMSEA= 0.020 < 0.05 with Pclose= 0.449 > 0.05 are not significant. Likewise, other fit indices are roughly the same with the model-2a pointing to a good model fit; and its proven solution model-3 as the best hypothesised model.

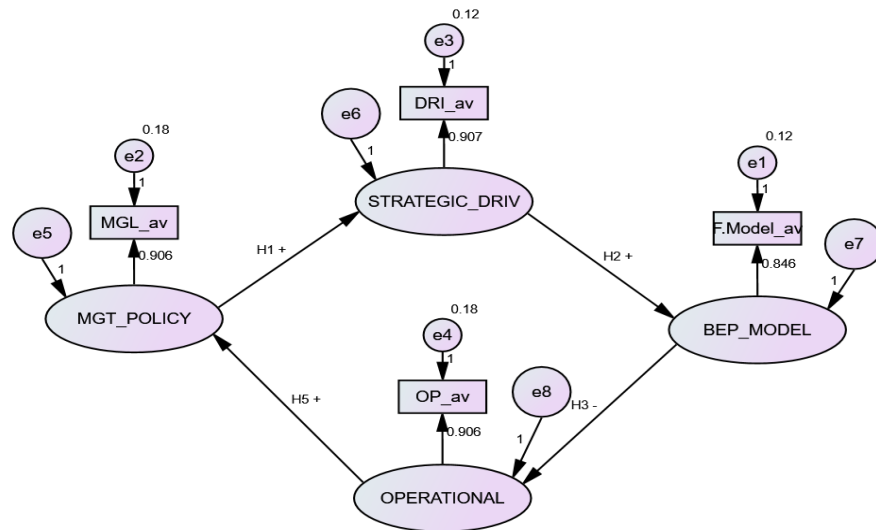


Figure 8.11: Composite Scale: Solution Phase Model-3a.

Paths'  $\alpha$ -values (H1, H2 and H5) results for model-3a are also significant. Whilst, H3 ( $\alpha$  = -0.068;  $z$  = -0.168;  $p$  = 0.867 > 0.05), is non-significant. Particularly, H1 ( $\alpha$  = 0.686;  $z$  = 2.038;  $p$  = 0.002) is significant at 0.05 level; while H2 ( $\alpha$  = 1.031;  $z$  = 5.175), and H5 ( $\alpha$  = 0.621;  $z$  = 4.319) are significant at 0.001 significance level.

Consequently, model-3a is also beneficial for examining the causal relationship between the constructs. Model-3a factors have standardised residual covariance values less than 2.0 absolute values. Hence, is correct at probing the causal effects between study construct; and could be applied to the general population or larger sample size. Although, the model indicated a good fit, but cannot be classified as 100% perfect; hence, the need to check for mediating effects in its structure.

### 8.8.3 Models' Direct, Indirect and Total effects

The total effects are used in decomposing the observed and latent variables' effects on one another. Effects decomposition is used to illustrate which latent variable has the largest effect and the greatest effect on the measure. *'The Total effect is the sums of powers of the coefficient matrices'* (Bollen, 1987) pg38). Bollen (1987), asserts that direct effects are those influences that are not mediated by any other circumstance.

The study's result indicates the standardised direct, indirect and total effects of each construct on one another for model-2a and model-3a (Table 8:16). In model-2a, the operation of the BEP sub-theoretical account is touched on directly by strategic drivers (0.81), and indirectly from management policy (0.51), in significant power. It created an indirect effect model (Jenatabadi and Ismail, 2014). Individual construct had good shares of its variances management policy (35.0%), strategic drivers (40.0%) and BEP model (65.0%) of the variances in respective constructs.

Table 8:16: Diagnostic and Solution Models: Standardised Estimates on Effects.

Model-2a and 3a Standardized Direct Effects on Direct, Indirect and Total Effects												
	Direct				Indirect				Total			
Comp. Model-2a	OP	Strat.	Policy	BEP	OP	Strat.	Policy	BEP	OP	Strat.	Policy	BEP
Strategy			0.63								0.63	
BEP_Model		0.81					0.51			0.81	0.51	
Operations			0.69	0.04		0.03	0.02			0.03	0.71	0.04
Comp. Model-3a	OP	Strat.	Policy	BEP	OP	Strat.	Policy	BEP	OP	Strat.	Policy	BEP
Operations				-0.06	-0.02	-0.05	-0.03		-0.02	-0.05	-0.03	-0.06
Strategy			0.67		0.48	-0.22	-0.02	-0.03	0.48	-0.22	0.65	-0.03
Policy	0.73				-0.02	-0.03	-0.02	-0.04	0.72	-0.03	-0.02	-0.04
BEP_Model		0.82			0.39	-0.02	0.54	-0.02	0.39	0.802	0.54	-0.02

Herein, the direct effect of strategic driver on BEP (0.81), is significant and greater than the indirect effect of policy on BEP sub-model (0.51). The strategy construct act as a mediator between management policy and the BEP constructs; and is both an exogenous and endogenous variable. Whilst management policy caused significant and strong direct impact on operational solution (0.69); the BEP sub-model direct effects on operational solution (0.04) is weaker (Byrne, 2010).

In paths H2 and H3, the relation between strategic drivers and BEP (1.013) is significant at 0.001 significance level; and that between BEP and operation (0.042;  $p = 0.833$ ) is not significant, indicating no mediation. However, strategic driver effects on BEP (direct and total) are the strongest effects (0.81) on BEP amongst the constructs association.

Standardised effects in the model-3a (Table 8:16), likewise shows, model constructs have total effects on one another. Management policy has significantly strong direct (0.67) and total effects on strategic driver construct (0.65); and it accounts for about 44.6% of variation in strategy construct. Also, policy has strong indirect and total effects on performances of the BEP sub-model (0.54). It means that strategic driver's construct is both endogenous and exogenous variable as well a mediator between management policy and BEP.

Strategic driver has strong positive direct and total effects on BEP (0.80); and weak negative indirect effects on operational (-0.05), and policy (-0.03). Strategic drivers construct accounts for 64.3% of variances in BEP construct; BEP accounts for 0.0% of variances in operational; and operational construct accounts for 44.6% of variance in management policy construct. However, it could be observed that the total effects of operational solution on strategy (0.48), policy (0.72) and BEP (0.39) are positively strong for the solution model.

#### 8.8.4 Mediating Effects and Hypothesis testing

Indirect effect occurs when the effect of one variable (either observed or latent) is affected (in whole or part) by a change in the effect of another or more intervening variables. Its specification is an important part of path analysis and latent variable structural equation models (Leth-Steensen and Gallitto, 2016), hence useful in the study.

Five hypothesised paths, mediation paths and five mediators are identified in both structural composite models (2a and 3a).

##### *I. Mediating Effects*

Model-2a mediation paths are:

- Path1: management policy → strategic driver → BEP; and mediator is strategy
- Path2: strategic driver → BEP → operational; and mediator is BEP.

Whilst model-3a mediation paths are:

- Path3: BEP → operational → management policy; and mediator is Operational
- Path4: management policy → strategic driver → BEP; and mediator is strategy
- Path5: strategic driver → BEP → operational; and mediator is BEP.

The unstandardized regression weight  $\alpha = \alpha$  is used in calculating the indirect (mediation) effects of the different paths based on the formula in equations 9.1 and 9.2 (Math, 2015), below:

$$\alpha = SE_{ab} = \sqrt{(SE_a)^2 \times b^2 + (SE_b)^2 \times a^2} \quad \text{Equation 9.1}$$

$$Z\text{-value} = \frac{a \times b}{SE_{ab}} \quad \text{Equation 9.2}$$

Where  $SE_a$  is the standard error of unstandardised regression estimates for a;  $SE_b$  is the standard error of unstandardised regression estimates for b. The unstandardised regression weight ‘a’ and ‘b’ are the path estimates. Whilst Z-value is the critical ratio, which must be > than 1.96 to be significant (Math, 2015).

Table 8:17: Model-2a and Model-3a Mediation Paths

Model-2a and Model-3a Mediation Paths					
Model Mediation Paths	Mediator	ab	SE-ab	Z-value (ab/SE-ab)	Critical Z-value
Model-2a Path1: Mgt_Policy → Strat_Driv → BEP	Strategy	0.498	0.173	2.881	$\geq 1.96\pm$
Model-2a Path2: Strat_Driv → BEP → OP	BEP	0.043	0.173	0.246	$\geq 1.96\pm$
Model-3a Path3: BEP → OP → Mgt_Policy	Operational	-0.042	0.173	-0.244	$\geq 1.96\pm$
Model-3a Path4: Mgt_Policy → Strat_Driv → BEP	Strategy	0.536	0.173	3.099	$\geq 1.96\pm$
Model-3a Path5: Strat_Driv → BEP → OP	BEP	-0.070	0.173	-0.405	$\geq 1.96\pm$

The result of the z-statistics for testing the five mediation paths in the structural models is indicated (Table 8:17). The result reveals that composite standardised deviations for only two paths are above the critical value (z-value >1.96); whilst others fall within (z-value < 1.96). Model-2a path1 (z= 2.881 > 1.96), and Model-3a path4 (z= 3.099 > 1.96), confirms that strategic driver construct is the only significant positive mediator. Whilst BEP and operational sub-models (z > 1.96), are weak and not significant.

## II. Hypotheses Testing



The hypotheses help in examining the contributions of each construct to the overall models. Also, to understand how much each construct and their unique variables explain the performance of the BEP model in improving BEP. Still, Amos software could not perform hypothesised path's Bollen-Stine bootstrap bias statistics (confidence interval analysis: lower and upper bound; and p-value for each course). It gave an error of the singular covariance matrix.

Such error (singular or near singular covariance) could arise when there is an issue of Multicollinearity, outliers, missing data, small data or even when all respondents' views are alike. However, it was earlier confirmed that the condition of Multicollinearity is not violated, there are no missing data, and adequacy of test of normality except data size have been established in the current study. The only exception is the respondents' similar agreement on research questions with no significant differences. It is obvious as the fifty-six variables presented are common knowledge to educate and well-informed participants of subject matter for the cogitation.

Whilst study hypothesis states:

*There are no significant causal relationships between operational, management policy, strategic driver and BEP sub-model (Hypotheses H<sub>1</sub>, H<sub>2</sub>, H<sub>3</sub>, H<sub>4</sub>, H<sub>5</sub>, H<sub>6</sub>, H<sub>7</sub> and H<sub>8</sub>).*

Table 8:18: Result for Hypothesis Tests

Hypotheses Testing Based on Composite Scale Models- 2a and 3a.							
Null Hypothesis	Paths	Total Effects	$\beta$ -value	Z-values	Probability	Null Hypothesis Results	Alternative Hypothesis Results
Model-2a							
H1	Policy → Strategy	0.63	0.63	4.487	0.001*	Rejected	Supported
H2	Strategy → BEP	0.81	0.81	5.885	0.001*	Rejected	Supported
H3	BEP → Operations	0.04	0.04	0.211	0.833	Supported	Rejected
H4	Policy → Operations	0.71	0.69	3.866	0.001*	Rejected	Supported
Model-3a							
H5	Policy → Strategy	0.65	0.67	3.150	0.002	Rejected	Supported
H6	Strategy → BEP	0.80	0.82	5.175	0.001*	Rejected	Supported
H7	BEP → Operations	-0.06	-0.06	-0.168	0.867	Supported	Rejected
H8	Operations → Policy	0.72	0.73	4.319	.0001*	Rejected	Supported

\*p<0.001

In Model-2a Path1, the alternative hypothesis states that there are causal relationships between policy, operational, strategy and BEP constructs. Strong positive correlation (r) exists between the three pairs of constructs, and their paths account for a significant percentage of their

variance ( $r^2$ ). H1 ( $\beta = 0.630$ ;  $z = 4.487$ ;  $r = 0.426$ ; and  $r^2 = 18.2\%$ ); H2 ( $\beta = 0.810$ ;  $z = 5.885$ ;  $r = 0.528$ ; and  $r^2 = 27.9\%$ ); and H4 ( $\beta = 0.690$ ;  $z = 3.866$ ;  $r = 0.461$ ; and  $r^2 = 21.3\%$ ), are significantly strong with  $p < 0.001$ . These paths' alternative hypotheses are accepted, hence, causality is confirmed for H1, H2 and H4 in model-2a (Table 8:18). Whilst, path H3: ( $\beta = 0.040$ ;  $z = 0.211$ ;  $p > 0.833$ ;  $r = 0.250$ ; and  $r^2 = 6.3\%$ ), is not significant and weak; thus, causation is denied for H3.

Model-3a hypothesised path: H5 ( $\beta = 0.670$ ;  $z = 3.150$ ;  $p > 0.002$ ;  $r = 0.426$ ; and  $r^2 = 18.2\%$ ); H6 ( $\beta = 0.820$ ;  $z = 5.175$ ;  $p > 0.001$ ;  $r = 0.528$ ; and  $r^2 = 27.9\%$ ); and H8 ( $\beta = 0.730$ ;  $z = 4.319$ ;  $p > 0.001$ ;  $r = 0.461$ ; and  $r^2 = 21.3\%$ ), hypothesised paths' coefficient of determinations is similarly significant; and same with those in model-2a. Too, the alternative hypotheses are accepted, hence, causality is established for the three paths (Table 8:18). However, Model-3a path H7 ( $\beta = -0.060$ ;  $z = -0.168$ ;  $p > 0.867$ ;  $r = 0.250$ ; and  $r^2 = 6.3\%$ ), is negatively non-significant, therefore there is no causal relationship.

## 8.9 FINDINGS AND DISCUSSION

The main finding shows identified SBM solutions for BEP that fits into a structural/measurement model based on study theoretical model. The outcomes of the test (Table 8:17 and Table 8:18), for structural relationships (hypotheses) amongst model paths also, indicate causality and mediations for the structural paths.

Study established that management policy causes strategic drivers to assist in the overall BEP improvement. For strategy to bear influence on BEP in an office building, it must be backed up with management policy. Therefore, strategic driver (identified tasks and staffing) is established as a mediator between policy and overall BEP model. Likewise, for critical operational solutions to aid desired result, it must be underpinned by management policy. Operational procedures must align with organisational policy to achieve BEP, hence causality is also shown.

Findings show that data collected supports study theoretical model, as all fit indices indicates that developed models are well fitted. The model development results indicate that reduction

in BEU and improved BEP can be achieved through a combination of operational effects, management policy, strategic sub-set of drivers and a unique BEP sub-model as critical factors.

The final measurement and structural models (model-1, diagnostic model-2, and solution model-3), met most fit criteria after modifications. Moreover, models' evaluation reveals that all composite scale models (diagnostic model-2a and solution model-3a), have good fits. Their RMR (ranges from 0.00- 0.040 < than 0.080), and Bollen-Stine's ( $p = 0.080 - 0.960 > \text{than } 0.500$ ), indicates overall model fit and test of null hypothesis fit well data collected.

Findings indicate dependency and interdependency relationships exist amongst constructs; and in between construct and indicators in the measurement variables. The interrelations between constructs is discussed as follows:

#### *I. BEP construct*

Study findings established six critical factors for the BEP construct as a sub-model. They are organisations' consideration for: climate change issue based on building mitigation and adaptation measures preparedness (Wilkinson, 2012); sustainable building management (SBM) policy based on BAM policy and plan (Jones et al., 2013); operations FM (Elmualim et al., 2010); instituted EE drivers and prevailing barriers (Parfomak, Sissine and Fischer, 2009); regulations and standards as externalities (Gabe, 2016); and existing LZC intervention installations (Ma et al., 2012; Olawuyi, 2013).

#### *II. Management Policy construct*

Three management policies are established in the study model: strategic sustainability policy (SSP), strategic facilities management (SFM) and strategic energy management (SEM) (Pitt and Hinks, 2001; Ikediashi, Ogunlana and Ujene, 2014), and are found to be critical to improving the overall BEP model. Management policy is fundamental to SBM and low carbon buildings for organisation. For an organisation to improve its BEP, it needs SSP, SFM and SEM as sub-set of policy incorporated into its core management policy.

The current study models revealed strong correlation and covariance (cv.) exists between: SSP and SFM policies ( $r = 0.77$ ;  $cv. = 0.42$ ); SSP and SEM ( $r = 0.64$ ;  $cv. = 0.38$ ); SFM and SEM ( $r = 0.69$ ;  $cv. = 0.42$ ), to achieve BEP improvement. Also, across constructs, SFM was found to influences strategic drivers such as PMs/KPIs (covariance= 0.34) and RETOs ( $cv. = 0.34$ ). It

has a strong covariance relationship in the efficient working of the BEP model. This indicates that SFM (amongst the three policies), underpinned the optimal performance of the BEP model.

### *III. Operational construct*

Findings also established the use of modelling (Model use) for energy monitoring and control; energy assessment (Assmnt); and energy audit (Enrgy.Audit) as most critical operational solutions sub-model for improving BEP. The result indicated energy assessment and audit ( $r=0.81$ ;  $cv. = 0.58$ ), are highly associated with each other; and equally exhibits strong correlations with the use of models. Energy assessment can only be fully optimised when combine with modelling ( $r= 0.69$ ;  $cv. = 0.50$ ). Similarly, energy audit cannot achieve its wide potential of aiding to improve BEP, except when use in junction with a model ( $r= 0.65$ ;  $cv. = 0.44$ ) as operational solutions for BEP improvement.

This suggests that the three components are vital components of BEP improvement measure for an office building. Operational factors (assessment, audit and use of model), are used for diagnostic and feedback loop purposes. They cannot directly influence BEU reduction and improve BEP but can influence management decisions (policy formulation); and aid instituted strategic drivers in achieving BEU reduction and BEP. Hence, operations have greater indirect effects on the BEP sub-model than its direct effects.

### *IV. Strategic driver construct*

The use of combined SSP and SFM, standardised performance metrics (PMs) and key performance indicators (KPIs); installations of renewable technologies (RETOs), engaging strategic energy management as strategic function; and installation of building energy technologies (BEMTechs) are also established as critical factors for improving BEP through consumption reduction (Agha-Hosseini et al., 2013). The role of these strategies provides a theoretical foundation for the relationship between BEP sub-model and policy including operations.

There exists a very strong positive relationship between combined SSP and SFM with BEP sub-model variables. The relationships between SSP.SFM and: LZC ( $r= 0.516$ ;  $cv. = 0.27$ ); climate ( $r= 0.510$ ;  $cv. = 0.28$ ); barriers/drivers ( $r= 0.455$ ;  $cv. = 0.21$ ); operational FM ( $r= 0.439$ ;  $cv. = 0.22$ ); and that of SBM.BAM ( $r= 0.411$ ;  $cv. = 0.20$ ), are the strongest amongst variables across constructs. Whilst, other strategic drivers such as: BEMTechs, PMs/PKIs RETOs and

SEM have smooth moderate relationships ranges between  $r = 0.310$ -  $0.430$ ; and cv. between  $0.10$  and  $0.19$ . This implied that strategic drivers interact with factors of BEP; and combined SSP.SFM has the greatest influences on BEU reduction and hence, improving BEP as a system.

#### V. *Aggregate Constructs' Relationships*

Decomposition of composite elements aggregates relationships based on sampled and implied correlations, establish strong positive connections between the constructs. To gain an improved BEP using the BEP model, the results prove that: operations depend on management policy ( $r = 0.47$ ); strategic drivers depend on management policy ( $r = 0.43$ ); and BEP depends on strategic driver ( $r = 0.53$ ). While a smooth moderate association exists between others, such as: operations will depend along the strategic drivers ( $r = 0.29$ ); operations depend on BEP ( $r = 0.25$ ); and management policy depends on BEP ( $r = 0.27$ ).

A two-way positive relationship is simultaneously established for between constructs. The covariance indicates that: operations and management policy (cv. =  $0.24$ ); strategic drivers and management policy (cv. =  $0.16$ ); and BEP and strategic driver (cv. =  $0.17$ ), impacts one another strongly. Likewise, there is an interdependency between: operations and strategic drivers (cv. =  $0.12$ ); operations and BEP (cv. =  $0.11$ ); and management policy and BEP (cv. =  $0.13$ ), resulting in a smooth moderate impact on one another.

The study identified the critical path to BEU reduction and improved BEP for the overall BEP model. It established strong covariance for: SSP-SFM (e11) to Climate (e1); SSP-SFM (e11) to LZC (e2); and SSP-SFM (e11) to BAR.DRI (e3), having high covariance (cv.) of  $0.27$ ,  $0.34$  and  $.31$  respectively. Also, critical, is the paths from SFM (e13) to RETOs (e7); and SFM (e13) to PMs/KPIs (e8) with cv. of  $0.34$  each. Furthermore, energy assessment to audit (e15-e16) (cv. =  $0.40$ ), established strong covariance. They reveal the most critical path way in the overall BEP model.

### 8.10 BEP MODEL PROCESS AND REFINEMENT

The study framework was reviewed based on the results of the five studies (qualitative and quantitative) established in the current research. The final framework (Figure 8.12) illustrates the 43 critical factors that affect case study's BEP.

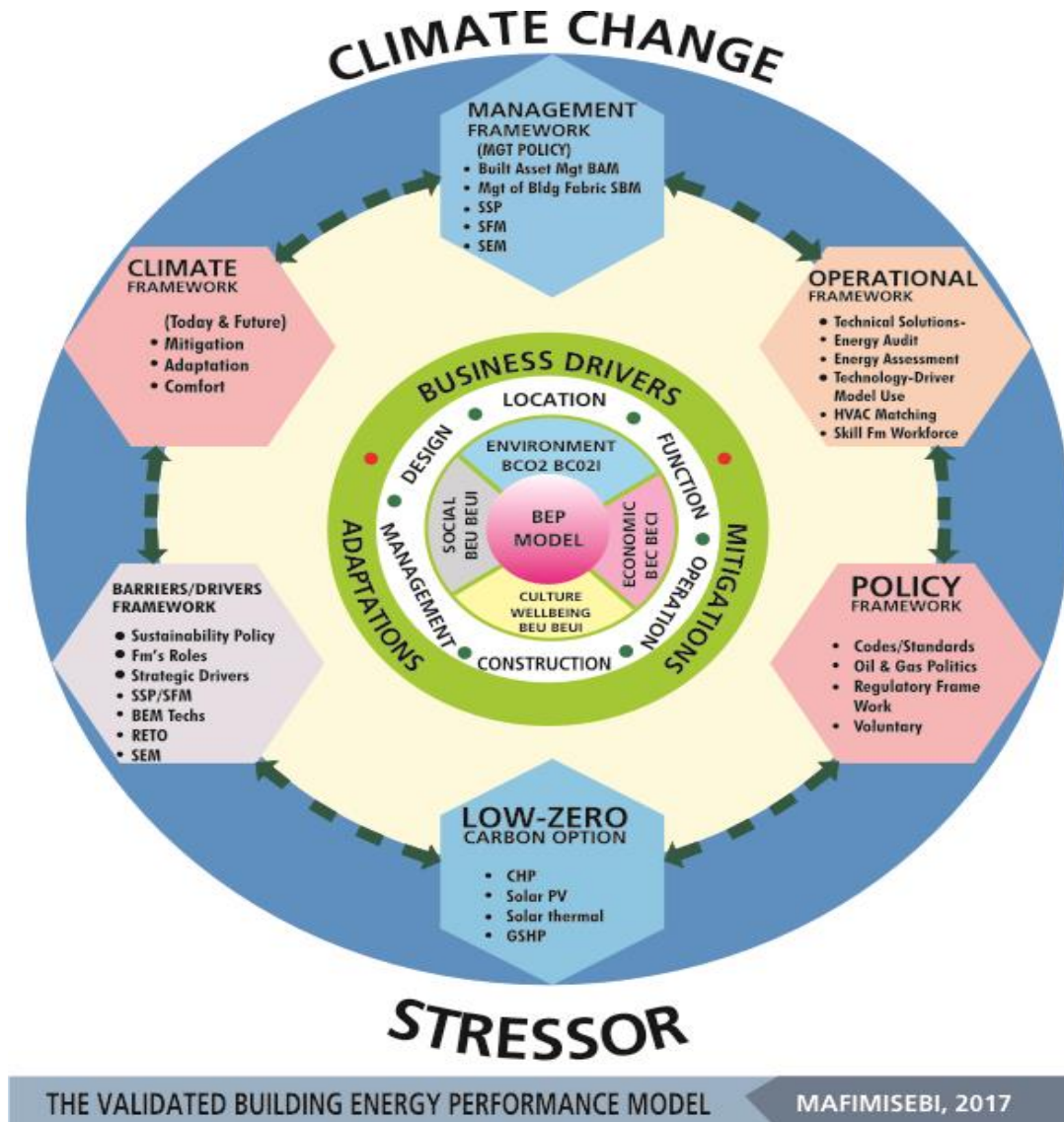


Figure 8.12: Final BEP Framework Model- Critical Factors

The critical factors (43) were further reduced to 17 most critical factors based on the study's BEP model via SEQM. The modelling process and refinement are illustrated as thus:

#### 8.10.1 Need Identification

The first step in the model process was the identification of the critical factors affecting a BEP. This was achieved through the study framework. Based on the framework variables, the OST was deployed in case buildings via physical energy audit and survey of archival documents. This serves as an appraisal tool for assessment of energy needs, and underperforming areas.

### 8.10.2 Establish cause

The second step was the delineation of problems and causes of underperforming areas and energy requirement. It is necessary as the underlying principle is to establish causes of poor BEP and associated interventions require for improvement. In achieving effective diagnosis, inquiry toolkits: meter reading, BMS data collection, interviews, case study report based on the OST, and POE were engaged in both qualitative and quantitative analyses.

The final model protocol involved three stepwise processes. First, it used the eight study's contexts as indicators of the BEP sub-model (shown in Figure 3.1). Secondly, the fifty-six framework variables were used as indicators of the eight contexts (as a construct-models) in the study's framework (represented in Figure 7.15). Finally, the eight construct-models and their indicators were then tested with the BEP fitted-sub-model to aid the improvement of the overall BEP model (shown in Figure 8.2). The initial decomposition of the model reveals that these contextual factors have both direct and indirect impacts BEP as thus:

#### *I. Management Policy*

Management policy based on SBM via adaption and mitigation strategies such as BAM, SSP, SFM and strategic energy management (SEM) were found to be the most critical factors that impacts BEP. BAM was however, dropped in the final BEP model via SEQM due to its negative variance in the CFA during the modelling process.

#### *II. Operational*

The used of operational subsystems for BEP based on strategic policies is acknowledged through study developed operational interventions. The study identified the lack of: skilled FM, regular energy assessment and audit, PMs/ KPIs, and model for energy assessment as the operational issues hindering BEP. The current model presented operational keys for handling all strategic plans in organisation.

Herein, the operational model involves implementing and monitoring policy by the competent FM team on daily routines to improve BEP. To achieve operational sustainability, the model used metrics such as: technology embedment, technical interventions, and operational solutions (for regulated and unregulated energy), as techniques for interventions.



The toolkits help provides quantitative data and identify interventions that support building climate adaptation and improved BEP. This is very critical, as the lack of quantitative data supporting climate related-threat; and lack of access to sufficiently robust data by management hinders acceptance of building climate by organisations (Jones et al., 2013). Consequently, case buildings were assessed based on these latent variables (metrics) and their indicators (sub-metrics) in obtaining reliable data on BEP.

### *III. Culture*

The culture index measured user's behaviour towards BEE and response to climate change. The participants' habit, attitude, norms, intention, behaviour in relation to BEU; and the requirement for a BCT were examined. Although current study, established that cultural influences (based on users' norms, habitus, intention and behaviour), have indirect impact on BEP and CO<sub>2</sub> emissions. However, the EFA indicates that culture and all its indicators communalities and factors loadings were very low; and as such, were dropped from the SEQM modelling validation process.

### *IV. Business Practice*

The concept of sharp practices, corporate social responsibility, and energy supply chain management were examined. These variables were used to investigate how corporate practices affect energy generations, supplies, use and BEP. The final validation SEQM model, found that they were impacting factors but are not vital enough to be admitted in the final SEQM modelling due to low factor loading.

### *V. Policy Framework*

Policy is another variable that has a direct impact on BEP of existing commercial stocks. The current study shows how developed countries have used regulatory policy guidance to stabilise BEU and improved BEP. Hence, the policy framework is considered as a factor that could influence low carbon building in Nigeria. Regulatory policy and incentivised measures have been successfully applied to mitigate against climate change and improve BEP globally. In the current study, policy index was used to measure the impacts of regulatory framework, building energy codes, and energy certification on existing commercial BEP.

### *VI. Strategic Drivers*



The strategic drivers in the final BEP model were derived from the barrier and driver index. The initial barrier and driver's indicators were reduced to SSP/SFM, SEM, PMs/KPIs and RETOs via the EFA and CFA in arriving at optimal solution. The strategic drivers were found to have direct impacts on BEP.

#### *VII. Low-Zero Carbon*

Low-zero carbon intervention has been substantiated to have an indirect impact on BEU, and a direct impact on carbon emissions and BEP. The installation of LZC technology in buildings is an intervention with direct impact, which could improve BEP but not necessarily reduce BEU.

#### *VIII. Climate*

The climate context represented an index of the final BEP construct model. It indicates the direct and positive impact of organisation's climate adaptation and mitigation policy on the BEP model and other factors like management policy, strategies and operations.

#### 8.10.3 Action statement

Report on improvement requirements based on modelled diagnosis is useful at this stage. An action plan that contains written statement of the problem and the cause was prepared. This also contained a mapping of performance standards (PMs/KPIs) and set targets. It was the project brief phase where proposed interventions are outlined, quantified and evaluated against desired outcomes.

#### 8.10.4 Solution Model Development

The used of AMOS software via SEQM to model optimal solutions for BEP for the study case buildings. It helped to identify the choice of optimal interventions, and the impact of solutions on the overall BEP model. The current study used EFA, CFA and structural equation modelling for final choice of interventions as illustrated in its application.

#### 8.10.5 Solution evaluation

This next phase was the usage of composite modelling for evaluation and establishing causality. The analysis of path coefficient of determination was performed to evaluate optimal

solutions and their impacts. The SEQM modelling tool was also deployed in this phase for objective analysis of the solutions for implementation described in its application.

### 8.11 MODEL APPLICATION

The process of the model refinement starts at the level of application of factor reduction via EFA. The initial 52-factor theoretical framework was reduced to 17-factor measurement and structural models, which explained 67.32% of the framework variances.

Consequently, for application purpose, the study established a new dual-model; diagnostic and solution models. The diagnostic model contains a feedback mechanism from diagnostic phase to solution implementation phase in path H1 → H4. The diagnostic phase starts with operational solutions (energy assessment, audit and use of operational framework) on an existing building (Figure 8.13). Policy feedbacks are received from management, and current energy performance feedback is received from BEP model. The result of diagnoses by these operations is forward to the management for input in strategic planning. The diagnostic application path is: Management policy → Strategic Drivers → BEP model → Operational → Management Policy → Operational.

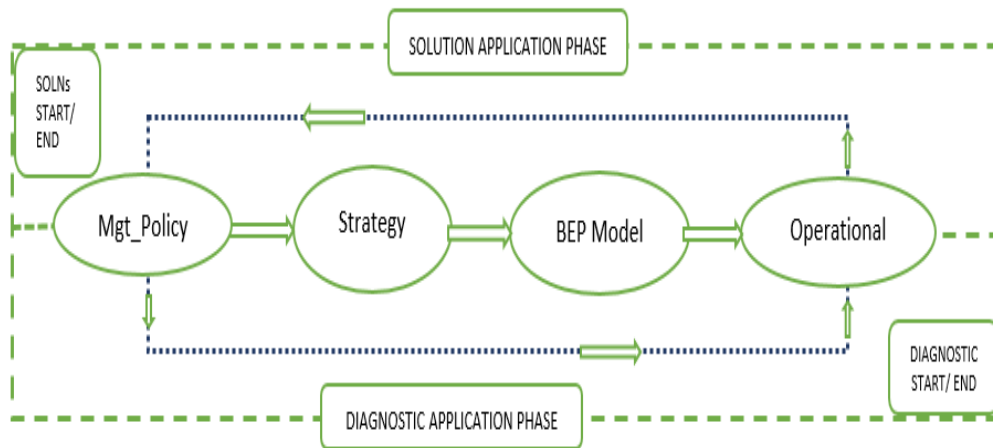


Figure 8.13: Study BEP Model Application's Flow Chart.

Whilst, the solution model starts at management policy to strategic drivers for improving BEP that are instituted based on the strategic plans; which are in turn used to drive the implementation based BEP model in path H1 → H5. The process application path is:

Management Policy → Strategic Drivers → BEP model → Operational → Management Policy. However, both phases (diagnostic and solution) are underpinned by the BEP model which is the outcome and truss of the study theoretical framework.

## 8.12 SUMMARY

The phenomenon of BEE involves environmental, economic and social factors (variables) that affects BEP. The chapter used SEQM through EFA and CFA to examine the critical factors that affects BEP; and the interactions (dependencies and inter-dependencies) between these contextual variables. It also, investigated structural relationship between the variables; and determine if collected data support theoretical model.

SEQM is applied based on the theoretical framework developed from substantive knowledge on these factors and the phenomenon of BEP. Therefore, theoretical basis guided constructs' validation and modelling in the chapter (Chin and Todd, 1995).

A BEP model is validated via SEQM based on study questionnaire 'Quest-surv3'. The EFA performed using maximum likelihood estimation produced a four-latent measurement model with 67.32% extraction sum based on Eigenvalue of 1.0. The model fit indicates KMO sampling adequacy of .86; and chi-square  $\chi^2(74) = 135.11$ ;  $p < \text{than } 0.001$  significance level. The new model comprised of seventeen factors and four constructs (operational, strategic drivers, management policy and BEP model) as components.

In the first construct BEP sub-model, EFA reduced the initial eight indicators in the theoretical framework to six reflexive indicators mainly: climate, SBM-BAM, operations, drivers and barriers, policy framework, and LZC. Business practices, and culture (behaviour) were dropped due low commonalities  $< 0.300$  and factor loading  $< 0.400$ .

Theoretically, culture and business practices are broad concepts that cannot be entirely tied down to the issue of BEE in terms of policy, tools and implementation. Although, occupant behaviour and business practices are critical crucial factors that also affects BEP, but they don't be seem to be completely measuring BEE alone as metrics and indicators. Hence, their non-inclusion was agreed after EFA extraction.

Model specification carried on the emergent model involves: the estimates of  $\beta$  between the underlying constructs and their observed indicators in the four-factor measurement model; and  $\beta$  paths between extracted constructs of structural model. Results showed model paths' coefficients and coefficient of determinations z-values are > than 1.96 recommended threshold, and are positive at p-values < than 0.001. Also, the assumptions of; Multicollinearity, linearity, homoscedasticity, invariance, positive definiteness, unidimensionality, and normality are met by the specified model. Hence, all EFA assumptions criteria were met in the SEQM.

Models' composite reliability is > than 0.700 Cronbach's alpha coefficient, and constructs' AVE lied between 0.737 (BEP) and 0.828 (Strategic drivers). Result indicated model's reliability and factorial validity are established. Whilst, constructs exhibited strong correlation amongst each other, and their correlation matrixes are < than 0.90 threshold. Thus, an evidence of common method bias was ruled out.

The SEQM's CFA is used to produce saturated models that tested study hypotheses; and examined interactions between IVs and DVs. Four construct models (strategic drivers, management policy, operational, BEP sub-model) are examined as single-factor models that formed both measurement and Structural models. In all, 4nrs construct models, 1nr measurement model, 2nrs structural models and their composite scale models (2nrs), are examined for: combine loadings, reliability, model fits and evaluations, effects interactions and hypotheses testing.

Results showed single-construct models' indices are good and above the recommended values as thus: BEP sub-model (CMIN/df = 0.751; p = 0.522; RMR = 0.011); management policy construct (CMIN/df = 0.001; p = 0.980; RMR = 0.003); operational construct (CMIN/df = 6.962; p = 0.008; RMR = 0.217); and strategic drivers (CMIN/df = 0.396; p = 0.852; RMR = 0.00). Whilst, models' overall fit and test of null hypothesis indicated good fits for SRMR (ranges from 0.00- 0.020 < than 0.080 threshold), and Bollen-Stine's (p = 0.080 - 0.960 > than 0.500 threshold).

The study test of eight hypotheses supported six alternative prepositions and rejected two. Hypothesis path: policy- strategy (H1); strategy- BEP (H2); and policy- operations (H4), have significant z-value > 1.96 for model-2a. Also, paths: policy-strategy (H5); strategy- BEP (H6);

and operations- policy (H8) for model-3a, have significant z-value  $> 1.96$ . They supported alternative hypothesis that causal relationship exists. Whilst, test for mediation is only established in mediation paths: management policy  $\rightarrow$  strategic driver  $\rightarrow$  BEP model path1 for model-2a; and same path5 for model-3a, have significant z-value  $> 1.96$ . Therefore, strategic driver is the only mediator in the two structural models.

Final framework model for the 43 critical factors that affect BEP was explained. While the ultimate BEP model based on the 17 most critical factors, including the modelling process, refinement and application was explained in the chapter.

## 9 Chapter Nine: Findings and Discussion

### 9.1 INTRODUCTION

This chapter present findings and discussions to the technical/ energy survey and the four studies (quantitative and qualitative), carried out in current research as presented in chapters six to nine. This is executed using the perspective of the worldwide body of knowledge and earlier discussions on extant literatures. It is guided by current research questions and structured to achieve the set study's objectives and aim.

The research questions summary table and the study objectives are used in reporting the discussion from each study based on triangulation and pattern matching; and inferences drawn. The summary (Table 9:1), present study's research questions (section1.6) as discussed in the present chapter.

*Table 9:1: Summary of Research Questions and Findings*

SN	Research Questions	Research Method Used	Requires Control of Behavioural Events?	Focuses on Contemporary Event?	Focuses on Phenomenon?
1	What are the critical factors influencing BEEP?	Survey, Case study, & Archival	No	Yes	Yes
2	What are the relationships and interdependencies between these independent factors and the EE of existing buildings in both countries?	Survey, Case study, & Archival	No	Yes	Yes
3	How could PMs and KPIs be identify and develop as a range of energy performance metrics and KPIs; and be integrated into new model based on multiple-case study method?	Survey, Case study, & Archival	No	Yes	Yes
4	What are the drivers and barriers that influence the effectiveness of the independent factors to affect EE of existing buildings?	Survey, & Case study	No	Yes	No
5	In what way can SP and FM drives the low carbon goal in existing buildings?	Survey, & Case study	No	Yes	No
6	How will study theoretical framework be translated into an integrated application for EE planning and operational based BEP management model?	Survey, & Case study	No	Yes	No

Research Questions and Methods used: adapted from Cosmos Corporation, (Yin, 2009).

## 9.2 DISCUSSIONS

### 9.2.1 Critical Factors influencing BEP in Nigeria compared to the UK

The following were identified as critical factors that affect BEP in fulfilling this research question.

#### *1. BEP based on Environment, Social and Economic indicators*

The Nigeria Cases' BEU reflected irregular pattern that is not weather dependent. The prevailing contexts presented were: irregularity and outrageous estimated bills from grid suppliers, frequent power outages, irregular invoicing for diesel purchases within organisations, and inadequate energy supply chain management. Hence, it could be deduced from this study that Nigeria office BEP depends largely on the context in which they operate in.

Inversely, the UK case BEU results certainly demonstrated the existence of controls on social, economic and environmental context. UK case BEU variations is explained by weather variability. Thus, the validity of climate variability as a critical factor of the UK case BEP is established. The differences serve as policy guidance for policy makers; in the design, formulation and implementation of energy policies in both countries.

#### *2. Climate Variability*

A profound inference drawn from findings in the current subject is that weather variations can only be a determinate of BEP based on the degree day theorem only if contextual variables are kept under restraint. EPL based on the OLS regression method, for Nigeria case buildings indicated that model defies the weather variability concept and invariably the Degree-days theorem. Hence, the EPL cannot be used to suggest or accurately predict these buildings' base load and BEU mainly due to data error from estimated billing system. Weather condition variability is not significantly related to BEU, therefore, not a predictor of its EEP in Nigeria.

Whereas, the UK case buildings' F-test satisfies the alternative hypothesis that the overall model coefficient is not equal zero. Findings confirmed that variation in heating degree-day is a significant predictor in the UK. Thus, the more obvious the uncontrolled social and economic variables of energy consumption in a country becomes prevalent, the less the influences of climate weather change on its existing office BEP.

The enactment of BEE regulations, adoption of ethical purchase policy via SP, installation of digital prepaid meter, and the incorporation of modern BEMTechs in offices could help improve existing BEP in Nigeria.

### *3. Share of Energy Source*

Energy source assessment in both countries indicates two major types of energy sources available for existing office building stocks. In Nigeria, fossil-fuel base electricity (84.2% share) and grid electricity (15.8% share), are dominant due to frequent power outages. The Nigeria case buildings use generators fuelled either by PMS or diesel (AGO). Whereas in the UK, fossil-fuel (natural gas with a share of 38.2%) and grid electricity (61.8% share), are prevalent due to economic consideration (energy cost). Nevertheless, the mode of generation differs, in Nigeria exists both on-site (use of generators) and off-site (grid-electricity) generations. In the UK, electricity is mainly off-site generated (grid-electricity and gas-electricity).

Two issues are associated with the Nigeria energy sources, which are environmental and economic sustainability. Current study established that air and noise pollutions; and huge fuelling cost (resulting in high recurrent expenditure for organisations) are associated with generators used in Nigeria buildings. Similar studies (Oyedepo, 2012; Ekpo and Bassey, 2016), have found that poor energy supply chain in Nigeria has imposed significant cost burden on the business sector of the economic system. Also, reduction in environmental quality because of air pollutants (particulate and gaseous), and noise pollution resulting in harmful physical and psychological effects on humans were linked to generator usage.

### *4. Billing method and Energy Data*

The study found that estimated billing method is practiced in both Nigeria and the UK with differences in operational modalities. However, the estimation billing system is associated with inaccurate data and outrageous energy bills with both countries. As established in the current study and confirmed in a past study (Stuart, 2011), estimated billing flaws energy data analysis and subject it to inaccuracies. It also leads to non-robust and unreliable energy consumption forecasting and planning. Hence, might not able to reveal actual energy performance of buildings. It is a critical barrier, since energy information management is an important part of strategic energy management; and billing data are invaluable resource.



A logical deduction is that, organisations as owners and operators of office buildings in Nigeria, are continually overwhelmed with energy crisis caused by more impactful social-economic factors already identified in the current study. Likewise, the socio-economic circumstance in which office buildings are functioning in, clearly overwhelms the phenomenon of BEU that should be supposedly dependent on weather variability. Consequently, national and organisation energy policies, and management strategy should be concentrated on eliminating estimation billing and related contextual EE barriers.

### *5. Contextual Issues*

Other critical factors as discussed (sections: 7.2, 7.3 and 7.4), were also shown to be influencing BEP. It was found that the overall BEP metrics determines contextual issues with both nations. It indicated energy management and policy key issues that organisations, government and professionals should keep track on. Those that are barriers should be either eliminated or minimised; and those that are drivers should be held in achieving BEU reduction and improved BEP.

The primary driver for UK energy consumption is the regulatory framework based on United Nations Framework on Climate Change (UN, 1992) and Kyoto protocol (UN, 1998) (Stuart, 2011). Regulatory policy framework is the underlying factor responsible for the less dominance of identified study's contextual factors in the UK compared to Nigeria. Consequently, similar stringent building energy regulation is suggested for Nigeria.

#### **9.2.2 Relationship and Interdependencies between identified Contextual factors**

The comparison between factors and between countries aided in inferences drawn for logical conclusions reached. It also aided in fulfilling this research question.

##### *1. User's Energy Behaviour*

The users' energy behaviour of cases in both countries reveals the energy culture. An example of the perceived behavioural control (PBC) indicates that occupants have common controls for lighting and shading in both countries. PBC has been proven to influence both intention and behaviour (Armitage and Conner, 2001b). Therefore, the difference shows that energy users in Nigeria have more PBC on cooling (64.7%), compared to UK's energy users' PBC on heating

(42.7%). The plausible deduction is that the THC sensors installed at  $20^{\circ}\text{C}\pm 1$  in the UK case buildings aided the difference. This reinforced the place of technology in taken over control from occupants, as driver of energy saving.

Findings on the EE habit indicates, that both users have more of the ‘I switch-off often’ habit than ‘I don’t switch-off’. Although, it was found to be higher for the Nigeria occupants ( $r = -0.660^{**}$ ), than their UK counterpart ( $r = -0.485^{**}$ ). It also reinforces the supposition that reliance on technology could reduce the habit of ‘switching-off-often’. The plausible explanation is that BEMS installation in buildings impact human attitude, habit, intent and perceived behavioural control as elucidated in Quest-surv1 results. Hence, occupants of buildings equipped with BEMS have a lesser EE habit of switching-off than users of buildings without BEMS.

Another factor that drives energy consumption and EE is intention. Studies have shown that intention drives actual energy behaviour (Armitage and Conner, 2001b). Also, intention as an indicator of attitude and normative norms (Chen, 2016), clearly determined user’s energy behaviour in both countries. The study three energy intention variables: conservation, reducing cost and CO<sub>2</sub> emissions are dominant with both countries.

The Nigeria’s users believed in stronger affiliation between energy conservation and reducing energy cost ( $r_s = 0.753^{**}$ ), than energy conservation and reducing buildings’ CO<sub>2</sub> emissions ( $r_s = 0.529^{**}$ ). While, their intent to ‘reduce-BEC’ and ‘reduce-BCO<sub>2</sub>E’ ( $r_s = 0.710^{**}$ ) is equally associated. Likewise, the UK’s users’ energy conservation intention is associated with the intent of reducing energy cost ( $r_s = 0.653^{**}$ ); and to reduce buildings’ CO<sub>2</sub> emissions ( $r_s = 0.610^{**}$ ). While their intent to ‘reduce-BEC’ and ‘reduce-BCO<sub>2</sub>E’ ( $r_s = 0.744^{**}$ ) is also aligned.

Results show that the Nigeria respondent’s intention of conserving BEU is strongly associated with the intent of reducing BEC. Occupants’ intention to conserve energy is connected to their intent to reduce BCO<sub>2</sub> emissions, hence, Nigeria occupants switch-off-often to conserve energy in order to reduce BEC. Similarly, the UK’s respondent’s intention of conserving BEU is strongly connected with their intent of reducing BEC. Hence, UK’s occupants’ intention to conserve energy is allied to their intent to reduce BCO<sub>2</sub>E.

The test on occupants' habit and intentions revealed the three forms of intention propels occupants' energy habits in both countries. However, conserve energy ( $r^2 = 51.5\%$ ) is the strongest, whilst reduce BEC ( $r^2 = 46.3\%$ ) and BCO<sub>2</sub>E ( $r^2 = 48.6\%$ ) are equally strong. Also, in both countries, the occupants' intention is the same and the three intent variables are totally inclusive and connected. This should be the focus of policy and behavioural change tools contents. It is important as EE information, awareness and campaigns, policy and programmes should be tailored to redress the underpinning issues with users' behaviour.

## 2. *Energy behaviour and Environmental Norms*

Study results posit that awareness on climate change (CCH) drives, sound environmental values in both countries. The awareness on CCH informed willingness to: change to more EE habit ( $r_s = 0.512$ ); reduce global warming ( $r_s = 0.452$ ); reduce BEU ( $r_s = 0.449$ ); and reduce building carbon footprint (BCF) ( $r_s = 0.426$ ), are strong with C's value between 0.31 and 0.36. However, awareness on CCH drives EE habits more than any other factor.

Awareness on BEP do also impact occupants' willingness to change to: EE habit ( $r_s = 0.448$ ); reduce BEU ( $r_s = 0.404$ ); and to reduce BCF ( $r_s = 0.465$ ) with C's value between 0.36 and 0.45. It was difficult for most of the participants to relate CO<sub>2</sub> emissions and Climate Change to buildings performance. The understanding of behavioural change is crucial for adaption and mitigation to CCH (Brody, Grover and Vedlitz, 2012). Hence policy and programmes should be focused centrally on EE habits; awareness programmes should delineate between CCH and BEP. This is important for understanding the critical factor influencing occupants' willingness to reflect it in policy guidance.

### 9.2.3 How PMs and KPIs could be Identified and Integrated into a New Model

The use of OS Tool for physical inspection (Appendix9), fulfilled this question by using identified PMs and KPIs as primary indicators and indexes for assessing the existing case buildings' BEP. It also aided in transforming the study theoretical model variables into a means of obtaining data across existing case buildings.

Several conclusions can be drawn from the use of OST. One is that the OS tool is able to aid physical assessment in terms of technical requirement of an EE performing building. For

instance, the OST classified Nigeria case buildings ('D' and 'E'); and all UK's case buildings ('A') in distinct categories. This disparity is later reflected in the EPL models of case buildings, thereby confirming the validity of the OST kit.

OS tool can illuminate the overview of the sustainability issues associated with the operations of these buildings. It further compared the management of case buildings across countries based on building's sustainability. Finally, the wide-ranging deduction drawn is that more contextual issues are associated with the Nigeria case BEU compared to the UK cases.

The study BEP framework based on prior knowledge underpinned the identified PMs and KPIs used as the OST primary indicators and indexes. Also, it transformed the framework into integrated an operational based BEP management model. Finally, the quantitative and qualitative data collected and analysed aided in improving the final BEP model, through the integration of the central BEP sub-model data with policy, strategy and operational process sub-model's dataset.

#### 9.2.4 Barriers and Drivers that Influence the Effectiveness of Critical Factors

Barriers and drivers established in the current study are already proven in extant literatures. Notwithstanding the founded relationship between these identified factor stands as a unique gap in knowledge that has been carried through by current study findings.

##### I. Barriers:

The understanding of existing barriers and their consequence based on interactions with one another, is critical for policy formulation and implementation of EE programmes. The lack of lack of regulatory policy/ institutional framework has several impacts on other factors in an organisation. Current study demonstrated that the absence of policy regulation is strongly associated with sharp practices ( $r_s = 0.465$ ). Similarly, the same affiliation pursuit for lack of building energy codes and standards (BEC&S) and sharp practices ( $r_s = 0.472$ ). It is thus established that the consequence of these barriers aggravates incidence of sharp practices.

A situation of the dearth of manpower and inappropriate energy consumption behaviour becomes prevalent in the absence of regulations. The relationship between: BEC&S and the lack of technical skill indicates ( $r_s = 0.549$ ); and BEC&S and inefficient behaviour & lifestyle ( $r_s = 0.444$ ), are also strong. Consequently, they are both correlated and causes lack of technical

skills in EE measures, and strongly impacts users' behaviour & lifestyle towards BEU reduction.

The implication for policy and practice is that, the lack of policy regulation and institutional framework portend consequences for the organisation and the countries. Thus, it could be construed that it is the underpinning critical factor, which leads to other identified barriers to BEP. This reinforced the global importance of regulations, codes and standards that have been used to reduce BEU (Pan and Garmston, 2012), and achieve BEP improvement.

Incomplete / imperfect information on BEE could aggravate: wrong behaviour & lifestyle ( $r_s = 0.582$ ); and the lack of technical skill ( $r_s = 0.572$ ). Imperfect information has strong linear correlation with both factors also.

## II. Drivers:

In driving energy savings and EE in buildings, it is important to understand the underpinning factors that influence them, and how they relate to one another. This will assist in policy guidance, preparation and implementation of EE measures.

The use of SSP and SFM in achieving low carbon building; and how it is accomplished in the six prepositions for identified drivers. The study findings for: SP/SFM and SEM ( $r_s = 0.671$ ); SP /SFM and BEMS ( $r_s = 0.670$ ); ESP/SFM and transparent/ ethical practice business (T&EB) ( $r_s = 0.681$ ); and ESP/SFM and assessment & benchmarking (PMs/KPIs), ( $r_s = 0.634$ ), all with C's value between 0.50 and 0.56, validate this assertion. Additionally, study results for renewable energy technology and SEM ( $r_s = 0.615$ ); also, proved strong positive correlations in driving BEP.

The current study advances that both SP and FM should be taken to a strategic management level in the organisation. Both policies (SFM and SSP) should be at the heart of core business strategy of governance in achieving effective energy management. This is sustained by the substantial and significant affiliations exhibited by the linkage between SSP/SFM and other EE drivers in the field. Also, it is profound that only SSP/SFM has the strongest coefficient ( $r_s = 0.63 - 0.68$ ); and highest coefficient of determination ( $r^2 = 0.49 - 0.52$ ), with each other identified driver. It has established the strategic position of the combined policies (SSP and SFM) in achieving low carbon goal.

### 9.2.5 Ways how SP and FM can drive the Low Carbon goal

The preceding results indicated that these factors (SP, SFM, SEM, SSP /SFM, BEMS and PMs/KPIs), present a strong network of critical EE drivers; and SSP/SFM is the underpinning factor upon which these relationships are built. As advanced in literature and the final BEP model, SSP and SFM should be integrated along with SEM in achieving improved EEP of an organisation BAM portfolio. A similar resolution has been upgraded in a past study (Jones, 2002) based on the role of strategic management as a central driver for building asset maintenance management. Thus, it fulfilled the research question of the used of SP and FM in driving low carbon goal in existing buildings.

### 9.2.6 Integration of Theoretical Framework into BEP Management Model

The BEP model is an assessment and benchmark that translate identified EE factors into technical, and operational base BEP management model. It established causality amongst its four constructs. This was shown in the dual-model variables' relationships as established: operations depend on management policy ( $z = 3.89 \text{ \& } 4.32 > 1.96$ ); strategic drivers depend on management policy ( $z = 4.49 \text{ \& } 3.15 > 1.96$ ); and BEP depends on strategic driver ( $z = 5.89 \text{ \& } 5.18 > 1.96$ ); whilst, strategic driver is shown as the only valid mediator between the constructs of management policy and the BEP sub-model ( $z = 3.10 \text{ \& } 2.88 > 1.96$ ). The demonstrated causality in the BEP dual-model, entrenched the validity of the model as a proactive framework that make BEU a principal target for reducing CO<sub>2</sub> emissions and improving BEP (Smith, 1997).

The final BEP model produced a synergy amongst a network of strategies that drives the BEP. It indicates a strong dependency and independence between: SSP and SFM policies ( $r = 0.77$ ;  $cv. = 0.42$ ); SSP and SEM ( $r = 0.64$ ;  $cv. = 0.38$ ); SFM and SEM ( $r = 0.69$ ;  $cv. = 0.42$ ). Hence, the indicated relationship amongst SFM, SSP and SEM is thus understood as the network of strategic drivers that propels BEP as validated.

Its pursuit to conclude that, the study identified the critical path in the overall BEP model. It established strong interdependent relationships between factors across the four constructs in the mannequin. For instance, the covariance between: SSP-SFM and Climate ( $cv. = 0.27$ ); SSP-SFM and LZC ( $cv. = 0.34$ ); and SSP-SFM and BAR.DRI ( $cv. = 0.31$ ), demonstrated across the

constructs of strategic drivers and BEP are strong. Also, critical, is the paths from SFM (in management policy construct) to RETOs (in strategic drivers construct); and SFM to PMs/KPIs (in strategic drivers construct), both with cv. of 0.34 each. A further strong covariance is established within operational construct from energy assessment to audit (cv= 0.40). They discover the most critical pathway in the overall BEP model.

SFM was found to influence these strategic drivers: PMs/KPIs (covariance=.34) and RETOs (cv. = 0.34), across constructs. This indicates that SFM (amongst the three policies), underpinned the optimal performance of the BEP model. This assertion corroborates the earlier conclusion that the combined SFM and SSP should be utilised alongside SEM in driving energy savings and BEP. Especially, all model factors and constructs are related and their connections are entirely mediated by the network of strategic drivers. Thus, a strategy is developed that gives these factors appropriate considerations in the operational practice and management of BEP.

Ultimately, the BEP model presents a quantitative approach that influenced the most critical issues amongst the vital elements that affects BEP. The outlined protocol aided in translating the theoretical concept into two BEP application tools (OS toolkit and the BEP model); and help achieved the study aim via a validated robust procedure built on academic rigour. Thus, it is sufficed to deduce that it bridged the gap between theory and practice.

### 9.3 SUMMARY

The current study used the six research questions as a frame for the discussion and exposition on findings from the five studies and result of the physical survey based on the OST. Triangulation and pattern matching techniques (Yin, 2014), are used for verification and establishment of forty-eight variables in the theoretical framework. The identified critical factors satisfied the condition of the first research question. Also, in answering the second research question, the studies identified critical barriers and drivers to BEP; and a delineation of their impacts on BEP.

Further examination of studies' finding and discussions were undertaken on the interactions and interdependency amongst identified critical factors. The results which indicated strong

affiliations and interdependency satisfied the conditions of the third research question. Moreover, the findings also revealed the strategic importance of combined use of SP and FM in driving low carbon goals for organisation's built assets management.

Whilst, the SEQM via AMOS produced a final BEP model that reveals final seventeen metrics and four constructs as study 'most' critical factors that affects BEP. The BEP model reduced the theoretical factors into EE strategic planning and operational BEP management based model, which satisfied the sixth research question.



## 10 Conclusions and Recommendations

### 10.1 INTRODUCTION

The current study presents the inferences made from the study's findings and the conclusions drawn. It further made useful recommendations on how to improve BEP of existing office building stocks. The suppositions are presented based on framed answers to the study aim and objectives. Finally, recommendations for owners, FMs, policy makers and future research are drawn from the findings and limitations to the current research.

#### Study Aim

- *'Develop an assessment and benchmarking framework that will enable owners and facilities managers to identify appropriate operational, technical and behavioural solutions for existing buildings in Nigeria'*

This is accomplished in the study final BEP model. The current study identified new indicators for BEP such as: BEP, management policy, operation and strategic drivers as standard metrics for the assessment and benchmark of BEP. This is a new knowledge as the fifty-two metrics were reduced to seventeen most critical factors that affects existing office buildings.

### 10.2 REVIEW OF RESEARCH OBJECTIVES

While, the study objectives are accomplished as follows:

- *'Identify the independent factors (strategic, operational, technical and behavioural) that affects existing BEP in Nigeria and the UK'*

The current study identified 52 critical factors that were transformed into 17 most critical factors impacting BEP in both states. The BEP model established causality in the most critical relationships between: management policy and strategic driver; strategic driver and BEP construct; management policy and operational solution; and operational solutions and management policy for both structural models. Whilst, strategic driver is established as the only mediator in the two models.

- *'Identify the relationships and interdependencies between the independent factors; and the use of SSP/ SFM for improving BEP in both countries'*

The study established relationship between user's habit and technology, it found that reliance on technology could reduce the habit of 'switching-off-often'. Also, users' intention was found to be strongly associated with energy conservation, BEC reduction and BCO<sub>2</sub>E. Whilst, awareness on CCH drives EE habits more than other factors. Therefore, EE information, awareness and campaigns for the governments and organisation's policy and programmes should be underpinned by these factors.

The BEP model established correlations and covariance between model's constructs and indicators; in-between constructs; and in-between indicators. Also, the findings prove that the use of SSP/SFM is the needed strategic solution for governments and organisations. This will increase the effectiveness of existing solutions and improving BEP. Disappointment often arises as implementations of technical solutions do not often yield the full potential and desired results. Investment in energy audit and assessment in improving BEP when compared to the result, do not always give the client value for money. These isolated solutions often lacked required links that could underpin their effectiveness, hence, the usefulness of the current BEP model.

It also found that these factors (SEM, Assessment& Benchmark, Renewable technologies, BEMS and T&EB) present a strong network of critical EE drivers; and SSP/SFM is the underpinning factor upon which these relationships are built.

The lack of regulatory policy is strongly associated with sharp practices. Likewise, the lack of building energy codes and standards (BEC&S) and sharp practices. Both relationships were found to be underpinned by regulatory policy as a most critical barrier. Whilst, incomplete / imperfect information on BEE aggravates wrong behaviour & lifestyle and the lack of technical skills. These barriers are more prevalent in Nigeria.

A driver like SSP/SFM has the strongest coefficient and the highest coefficient of determination with other identified drivers. Findings for drivers: SSP/SFM and SEM; SSP /SFM and BEMS; ESP/SFM and transparent/ ethical practice business (T&EB); and ESP/SFM and assessment & benchmarking (PMs/KPIs), were found to be strongly correlated and more predominant in the UK than Nigeria.

- *‘Identify the drivers and barriers that influence the effectiveness of the independent factors to affect existing BEP’*

The study identified critical barriers to BEP as a lack of regulatory policy, lack of building energy codes and standards (BECS), sharp practices, incomplete / imperfect, inefficient behaviour & lifestyle and the lack of technical skills, etc. Whilst, critical drivers are SSP/SFM, SEM, BEMS; assessment & benchmarking (PMs/KPIs), SP, FM roles; Renewable energy, etc.

- *‘Build up a theoretical framework model that relates the independent factors to the EE of existing buildings’*

The modelling process and refinement protocol including the OST established based on the study framework aided in relating model factors to BEEP of existing stocks.

- *‘Develop a series of performance metrics (PMs) and key performance indicators (KPIs) to measure the effect of the independent factors on the existing BEP’*

The BEP model and the OS tool helped in accomplishing this objective. The protocol, took off from a critical review of extant literatures through the formulation of theoretical frameworks; to transformation of variables into an OS assessment tool. Likewise, the final modelling of factors via SEQM; including how it was translated into the BEP Model’s seventeen metrics and four indicators was also unique.

- “Identify practical guidance on the application of the framework model to the Nigeria buildings”

The study found that the more obvious the uncontrolled social and economic variables of energy consumption in a country becomes prevalent, the less the influences of climate weather change on its existing office BEP. So, organisations as owners and operators of office buildings in Nigeria, are continually overwhelmed with energy crisis caused by more impactful social-economic factors.

The autonomous model and its OST thus, should be used as energy assessment and benchmark across heterogeneous commercial building stocks. The BEP model serves as a dashboard that

encapsulates BEP, and the impacts of intervening factors at current levels in absolute reality. It presents insight into the critical path for intervention schemes as implemented; and the use of the combined strategic SP and FM as mediation for improving BEP.

The model provides an analytical understanding of all formative indicators for BUE as indexes for measuring performance. Therefore, governments, policy makers and management could also use the model as a tool for: regulatory policy guidance; BCT policy; management policy decision-making; strategic policy guidance towards building climate mitigation; and advancement in operational and technical procedure (energy assessment).

### 10.3 RESEARCH LIMITATIONS

Several limitations were encountered during the research, nevertheless the most critical limitations were:

- The inability to get approval for use of buildings from educational institutions and other private organisations in Nigeria due to bureaucracy and lack of disclosure.
- The limited finance available for the researcher (self-sponsor) in executing the research project in two countries (Nigeria and UK).
- The limited time frame (two years) for carrying out such intensive and extensive (explanatory and exploratory) research across both countries;
- The current research used the 5-point Likert scale. However, if the universal 7-point Likert scale (-3 (cold) to +3 (hot)), for buildings' comfort measurement have been used, it may have given a different users' perception of the case buildings' thermal comfort; and
- The non-readily accessibility of experts on SEQM and the IBM AMOS software during the modelling process.

### 10.4 REVIEW OF RESEARCH FINDINGS

The current research examined the evidenced of CCH and concludes that climate is changing and the resultant changes impact buildings and occupants in the immediate and future. It established that CCH exposes people, societies, economies and the ecosystem to risks of uncertain occurrences that are in the form of hazard vulnerability. Also, it linked CCH to

consumption of fossil fuel and other sources of GHGs emitted; and established building as a major source.

Extant literature findings indicate that the EU's and UK's used Building energy codes and performances assessment guidance as CCH policy respond in achieving building sustainability; and as tools for improving BEP. The EU's instituted EPBD (2002/91/EC) and the UK's Climate Act 2008, places stringent demands on BEP, enhanced BEP and CO<sub>2</sub> emissions reduction. Particularly, the UK's strategic use of DEC's and EPC's alongside government rollout intervention schemes and programmes, have yielded successful results that could be replicated in SSA and Nigeria.

The study expounds that FMs developed a wide range of building adaptation and mitigation interventions. Improvement of existing building's systems is now integrated into strategic asset management to sustain business. Refurbishment of existing buildings, adoption of EE measures and renewable technologies are identified. Likewise, organisations now use strategic maintenance plan as their long-term BAM strategies. The study literature identified the various plans employed by FMs.

Findings on the impact of workplace interventions on employee satisfaction and productivity, confirmed that FMs introduce a range of operational and behavioural interventions into the workplace. Particularly, control of user's consumption behaviour is more prevalent due to the entrance of BEMS technologies. Whilst, operational FM interventions to existing building stock (controls equipment, efficiency measures, and non-technical initiatives, etc.), are found to be successful in the UK. Equally, retrofits of existing buildings, incorporation of renewable, adaptive reuse, etc., are successful CO<sub>2</sub> mitigation strategies that could be adapted to Nigeria's existing building stocks.

Management interventions such as: BEM, comfort and operational settings; strategic management; FM, SP and decision-support models by organisations were established. The uptake of EMS (ISO 14001), EN16001 standards and energy management system (ISO 15001; 2011), is effective BEP intervention policies. Likewise, FMs are now saddled with the responsibilities of SSP within the organisation. Hence, combined SFM and SFM as a core integration-tool, is considered useful for organisations.

The lack of integrated BEP framework underpinned by the BAM process as detailed business model to support cost/ benefit assessments for interventions' implementation was established. Current research addressed it by developing an assessment framework based on the four pillars of sustainability that enables owners and FMs identify appropriate BEP solutions.

The Nigeria case office BEP depends largely on the context in which they operate in. Whilst, the UK case BEU results certainly demonstrated the existence of controls on economic, social, cultural and environmental context. Hence, it was deduced that weather variations can only be a determinate of BEP based on the degree day theorem only if contextual variables keep under restraint.

Lack of regulatory policy and building energy codes & standards (BEC&S), are strongly connected with sharp practices. Both relationships were found to be underpinned by regulatory policy as a most critical barrier. Also, incomplete / imperfect information on BEE aggravates wrong occupant's energy behaviour & lifestyle and the lack of technical skills. These barriers are more prevalent in Nigeria. Whilst, a driver like SSP/SFM has the strongest coefficient and the highest coefficient of determination with other identified drivers. Results for drivers: SSP/SFM and SEM; SSP /SFM and BEMS; ESP/SFM and transparent/ ethical practice business (T&EB); and ESP/SFM and assessment & benchmarking (PMs/KPIs), were found to be strongly correlated and more predominant in the UK than Nigeria.

The implication for policy and practice is that, the lack of policy, regulation and institutional framework portend consequences for the organisation and the countries. It was construed as the underpinning critical factor, which leads to other identified barriers to BEP. This reinforced the global importance of regulations, codes and standards that have been used to reduce BEU (Pan and Garmston, 2012), and achieve BEP improvement.

The study also established relationships between user's habit and technology, it found that reliance on technology could reduce the habit of 'switching-off-often'. BEMS has impacts on user's attitude, habit, intention and PBC. Also, users' intention was found to be strongly associated with energy conservation, BEC reduction and BCO<sub>2</sub> emission. The awareness on CCH drives EE habits more than other factors. Awareness and complete information on environmental norms was found to positively impact occupant energy behaviour & lifestyle.

Therefore, EE information, awareness and campaigns for the governments and organisation's policy and programmes should be underpinned by these factors.

The current study accomplished the research aim through identification of new indicators for BEP (BEP, management policy, operation and strategic drivers), as standard metrics for the assessment and benchmark of BEP. It identified 52 critical factors that were transformed into 17 most critical factors impacting BEP in both countries. The BEP model established causality in the most vital relationships between its constructs. Strategic driver is established as the only mediator in the two models.

The BEP model established correlations and covariance between model's constructs and indicators; in-between constructs; and in-between indicators. Also, the findings prove that the use of SSP/SFM is the needed strategic solution for governments and organisations. This will increase the effectiveness of existing solutions and improving BEP. Likewise, it found that these factors (SEM, Assessment& Benchmark, Renewable technologies and BEMS) present a strong network of critical EE drivers; and SSP/SFM is the underpinning factor upon which these relationships are built.

## 10.5 IMPLICATIONS OF RESEARCH FINDINGS:

The research covers the understanding on how a worldwide research on prior knowledge of theoretical framework's variables could be distilled; and translated into PMs/KPIs in the form of OST and a final BEP model for assessment of case buildings. It, further, advanced into modelling of these factors into most critical factors that formed strategic planning and operational based management model. The BEP Model is a significant application of theory and practice. It is an exemplary fit in the application of theory to practice. It also aids to close the perceived gap between theory and practice.

Globally, some organisations have been using strategic drivers to accomplish management policies. However, it has been in fragmented form in terms of choice of a specific strategy. The current study measured the absolute and perceived impacts of sub-set of strategic drivers on BEU and BEP, which a new knowledge fulfilled.

Professionals and researchers could find the BEP model handy as it is both useful as a research advancement, operational and physical survey OS-toolkit. It also serves as both reactive and proactive tool for improving office BEP.

## 10.6 CONTRIBUTION TO KNOWLEDGE

The study established the following as newly fulfilled gaps in knowledge:

- The founded relationships that exist between identified critical factors stand as a unique gap in knowledge that was fulfilled.
- It has established the strategic position of the combined SSP and SFM policies in achieving low carbon goal.
- The demonstrated causality in the BEP dual-model, entrenched the validity of the model as a proactive framework.
- The study identified the critical path in the overall BEP model. It established strong interdependent relationships between factors across the four constructs in the BEP model.
- It linked assessment and benchmark with SP, strategic management process, and SFM operation process, which made it possible to measure their relationships and establish relations between factors
- Used of SEQM in investigating the factors (both latent and manifest) that affect BEP in Nigeria compared to the UK; and utilisation of the differences (variances) between these factors to determine their relationships and interdependency that established causality is useful for heterogeneous multiple-case study, finally
- It established that weather variations can only be a determinate of BEP based on the degree day theorem only if contextual variables are kept under restraint.

## 10.7 FINAL CONCLUSIONS

Regulatory policy framework (regulatory policy, building codes and standards), is the underlying factor responsible for the less dominance of identified study's contextual factors in the UK compared to Nigeria. Consequently, similar stringent regulatory framework is suggested for Nigeria and other SSA countries.



The BEP model is multivariate and complex. Nonetheless, the indices' toolkits made it an 'easy-to-use' and 'easy-to understand' operation-based model for owners and operational FM. It clearly delineates the critical factors that influence existing building stocks' energy use and efficiency performance. It also, expounded on the impact of interventions on BEP. The BEP sub-model relate these factors from concepts in extant literatures to the occurrence of BEU and BEP, unlike most existing models.

## 10.8 RECOMMENDATIONS

### 10.8.1 Recommendation for Owners

SP and FM should be taken to a strategic management level in the organisation. These policies (SFM and SSP) should be at the heart of core business strategy of governance in achieving effective energy management and low carbon goals. Besides, it helps owners of organisation to appreciate both perceived and absolute benefits of the integration of both policies. Owners' adoption of ethical purchase policy via SP, installation of digital prepaid meter, and the incorporation of modern BEMTechs in offices will improve existing BEP.

The model provides an analytical understanding of all formative indicators for BUE as indexes for measuring performance. Therefore, governments, owners, policy makers and management could also use the model as a tool for: regulatory policy guidance; BCT policy; management policy decision-making; strategic policy guidance towards building climate mitigation; and advancement in operational and technical procedure (energy assessment).

### 10.8.2 Recommendation for FMs

The BEP model could be translated into tangible computer software that could be incorporated into BIM for monitoring BEP via real time POE and BEU data that include performance information. This will help FMs in the day-day decision making. Also, the BEP reveal facilities performance status and invention requirement, which FMs could rely on as a decision-making tool.

FMs adoption of ethical purchase policy via SP, installation of digital prepaid meter, and the incorporation of modern BEMTechs in offices will help improve existing BEP in Nigeria and

the UK. FMs and owners should discourage estimated billing method, it could be minimised by putting a ceiling between  $\pm 5\% \geq \pm 10\%$  of the average annual cost of a building metered bill. This should be incorporated into the vendor agreement and subject to normalisation after actual meter reading.

Professionals and researchers could find the BEP model handy as it is both useful as research advancement, operational and physical survey model-toolkit. The model application of EFA, CFA and SEQM made it possible for researchers and FMs know the absolute impacts of each underlying factor and their respective reflexive indicators on BEP. It also serves to indicate the dependency and interdependency amongst these various BEP indicators. This will enable organisations to take both reactive and proactive actions against the poor energy performance of buildings and GHGs emission.

### 10.8.3 Recommendation for Policy Makers

The Nigeria and SSA countries' governments should emulate the UK Climate Act 2008, a legislation that underpinned the various UK successful action programmes. This can be instituted in Nigeria and SSA.

In aid to individuals and organisations, the Nigeria government can leapfrog into a low carbon economy through the uptake of UK exemplary schemes such as: feed-in tariff, renewable energy incentives and the energy company's obligation (ECO) schemes that have been successful in the UK.

Government and organisations energy policies and management strategies should be concentrated on eliminating estimation billing practice and related contextual EE barriers. Also, policy and programmes should be focused centrally on EE habits; and awareness programmes should delineate between CCH and BEP. This is important for understanding the critical factors influencing occupants' willingness to change to EE habit in formulating policy guidance.

### 10.8.4 Recommendation for Future Research

Future research should be undertaken to test the entire BEP model and OST variables based on a larger sample size ( $\geq 560$ ) and the SEQM technique. This could enhance the model; and

further ascertain the linkage of occupants' energy behaviour (culture) and business practices with other constructs in the final BEP model.

Further research should seek to address how Nigeria buildings could respond more to weather variation than social-economic context. Also, how better estimate billing method could be adopted to minimise or eradicated outrageous electricity cost and flaws in BEU data. This should base on an agreement between the service provider and owner; with ceiling between  $\pm 5\% \geq \pm 10\%$  as factor of the average annual cost of metered bill should be use as control.

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## Appendices

### Appendix 1A: UNFCCC COPs from COP1 (1995) to COP15 (2009)

UNFCCC CONFERENCE OF PARTIES: OVERVIEW OF DECISIONS FOR COP1 TO COP15. Part A					
UNFCCC: COPS	Venue	Year	Agreements, Accords and Decisions	Decisions	Resolutions
COP1	Berlin, Germany	1995	Agreed to establish a process to negotiate strengthened commitments for developed countries	21	1
COP2	Geneva, Switzerland	1996	No agreement on emission limit and reduction	17	1
COP3	Kyoto, Japan	1997	Consensus on Kyoto Protocol: agreement on Six major GHGs, Emission trading and Forest Sink methodological work	18	3
COP4	Buenos Aires, Argentina	1998	Agreed to focus on strengthen of financial mechanism, development and transfer of knowledge and maintaining the gains of Kyoto protocol	19	2
COP5	Bonn, Germany	1999	Agreed National communication guide lines, capacity building, transfer Technological and flexible mechanisms	22	nil
COP6	The Hague Netherlands; & Bonn Germany	2000	Consensus on Bonn Agreements, including capacity building for developing and transition economic countries.	6	3
COP7	Marrakech, Morocco	2001	Agreed on package deal, the Principle of LULUCF mechanism in data reporting and limited banking of unit generated by sink under the CDM.	39	2
COP8	New Delhi, India	2002	Ministerial Declaration of Climate Change and Sustainable Development	25	1
COP9	Milan, Italy.	2003	Adopted decisions on the institutions and procedures of the Kyoto Protocol; and on implementation of the UNFCCC. Also, agreed on emissions reporting guideline based on good-practice guidance, modalities and scope for carbon absorbing Mgt projects via CDM; special climate fund; and least Developed country fund that support technology transfer, adaptation projects etc.	22	1
COP10	Buenos Aires, Argentina	2004	Completion of Marrakech Accords and framework on future climate change	18	1
COP11	Montreal, Canada	2005	Addresses issues on effects of climate change on developing and least developed countries; capacity building, development and technology transfer; financial and budgetary issues (guideline to the global environmental facilities (GEF) that serve as financial mechanism	15	1
COP12	Nairobi, Kenya	2006	Agreed on Nairobi Framework on Mitigation on climate change; Nairobi work programme on impacts, vulnerability and adaptation; and Mgt of Kyoto Protocol adaptation fund	9	1
COP13	Bali, Indonesia	2007	Agreed on Bali Road Map (a two-year process of strengthening international climate change agreement; and Bali Action Map adopted by Decision 1/CP.13.	14	1
COP14	Poznan, Poland	2008	Established Adaptation fund with a 2% levy on project under the CDM; Adaptation Fund Board; and progress on Adaptation, Finance, technology and disaster mgt.	9	1
COP15	Copenhagen, Denmark	2009	The Copenhagen Accord is highest climate policy consensus so far with 115 Presidents of Nations in attendance. Agreed long-term goal for maximum 2oC temperature rise; Countries to communicate CO <sub>2</sub> emissions limit and effort biannually; and development of long-term Finance of US\$100 /year by 2020 for needs of developing countries.	13	1

Source: Study Author 2016



Appendix1B: UNFCCC COPs from COP16 (2010) to COP22 (2016)

UN CONFERENCE OF PARTIES: OVERVIEW OF DECISIONS FOR COP16 TO COP23. Part B					
COP16	Cancun, Mexico	2010	Agreed on the Cancun Agreed; Cancun Adaptation Framework; and set up of Adaptation Committee. Parties agreed to commitment to max 2 0C rise in temperature; a technological Mechanism by 2012, climate friendly technologies; and established green fund for financing developing countries	12	1
COP17	Durban, South Africa	2011	Adoption of Universal Climate Agreement by 2015; and 2nd commitment to Kyoto Protocol by 2013 based on the Principle of common but differentiated responsibilities.	19	1
COP18	Doha, Qatar	2012	Agreed on time table to adopt Universal Climate Agreement by 2015; launched 2nd commitment period for Kyoto Protocol (01/01/2013- 31/12/2020); and adoption of Doha Amendment to the Kyoto Protocol.	26	1
COP19	Warsaw, Poland	2013	Agreed on Alternative policy approaches (combined mitigation and adaptation) for the integral and sustainable management of forest; ways of reducing emissions from forest degradation and deforestations. Agreed on the Warsaw international Mechanism for loss and damages.	7	1
COP20	Lima, Peru	2014	Action on Climate change; implementation of the common but differentiated responsibilities principle; agreed on long term objective based on sufficient time framework to allow for the ecosystem to adapt naturally to climate change.	20	1
COP21	Paris, France	2015	agreed on holding global temperature at 2 0C; enhancing action on Adaptation based on Cancun Adaptation Framework; enhancement of capacity building of developing Parties; transparency action framework in communication, biennial reports, and biennial update reports, international assessment, review and analysis; agreement on strengthening climate awareness, education, training and public participation	29	1
COP22	Marrakech, Morocco	2016	agreed on matters relating to the implementation of Paris Agreement; Rule of procedures for COP third review on Adaptation Fund; Report of Adaptation Fund Board Guidance Relating the CDM, Gender and Climate Change; National Adaptation Plan; Long-Term Climate Finance, etc.	25	1
COP23	Bonn, Germany	2017	Pending	Pending	Pending

Source: Study Author 2016

## Appendix2: Millennium Development Goals

Millennium Development Goals (MDGs) from 2000-2015		Major Targets Achieved (by December 2015)
Goal 1	To eradicate extreme Poverty and Hunger	The numbers of people living in extreme poverty dropped by more than half from 1.9 billion in 1990 to 836 million in 2015, with most progress occurring since 2000.
Goal 2	To achieve universal primary education	Sub-Saharan Africa primary school enrolment increased from 8% points (between 1990 and 2000) to 20% point since 2000. While net primary school enrolment in developing regions has reached 91 per cent, up from 83 per cent in 2000.
Goal 3	To promote gender equality and empower women	Greater women representation both in parliaments; and schools around the world. Southern Asia achieved more than 74% girls for every 100% boys in school enrolment compared to 1990 records.
Goal 4	To reduce child mortality	Reduction in child mortality; and 1990 and 2015, the annual rate of reduction of under-five mortality has more than tripled globally. 45% worldwide since 1990, 64% in Southern Asia, and 49% in sub-Saharan Africa.
Goal 5	To improve maternal health	Maternal mortality ratio has been reduced by nearly half worldwide; three-quarters of births are assisted by skilled health personnel globally
Goal 6	To combat HIV/AIDS, malaria and other diseases	HIV infection rates dropped to 40 per cent (from 3.5million to 2.1million cases, increase in antiretroviral therapy, tremendous declines in malaria deaths and incidence rates as well as superior success in tuberculosis treatment
Goal 7	To ensure environmental sustainability	90% of world population have access to drinking water; and Ozone protection efforts virtually eliminated ozone depleting substances.
Goal 8	To cultivate a global partnership for development	66% increment in official development assistance (ODS) from developed countries.

Adapted from: UN, 2015



### Appendix 3A: Agenda 2030 Sustainable Development Goals

Agenda 2030 Sustainable Development Goals (SDGs)		Major Targets from 2016 to 2030
Goal 1	Eradicate Extreme Poverty and Hunger	By 2030: eradicate extreme poverty everywhere in the world (metric people with < \$1.25 per day); reduce by 50% the population of people living in all forms of poverty; build the residence of the poor and those in vulnerable situations
Goal 2	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture	By 2030: end all form of malnutrition; double agricultural productivity and income of small-scale food producers; ensure sustainable food production system; and implement resilience agriculture practices, etc.
Goal 3	Ensure Healthy lives and promote wellbeing for all at all ages	By 2030: reduction of global mortality ratio to < than 70 per 100,000 live births; end epidemic of AIDS, tuberculosis, malaria, and neglected tropical diseases; substantially reduce the cases of deaths and illness from hazardous chemical and air, water and soil pollution and environment, etc.
Goal 4	Ensure inclusive and equitable quality and promote life-long opportunities for all	By 2030: ensure that all girls and boys complete free, equitable and quality primary and secondary education; eliminate gender disparity in education and ensure equal access to all levels of education; ensure that all learners acquire knowledge and skills needed to promote sustainable development, etc.
Goal 5	Achieve gender equality and empower all women and girls	By 2030: end all forms of violence against women and children in public and private sphere, including trafficking and sexual and other exploitation; ensure women's full participation and equal opportunities for leadership at all levels; use ICT to promote women empowerment etc.
Goal 6	Ensure availability and sustainable management of water and sanitation for all	By 2030: ensure universal access to safe and affordable drinking water for all; access to adequate and equitable sanitation and hygiene for all, and end open defecation; improve water quality by reducing pollution; implement integrated water resources management at all levels, etc.
Goal 7	Ensure access to affordable, reliable, and modern energy for all	By 2030: ensure universal access to affordable, reliable and modern energy service; increase substantially the share of renewable energy in the share of global energy mix; double global rate of improvement in energy efficiency; expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, particularly LDCs and SIDS.

Adapted from SDKP, 2017

### Appendix 3B: Agenda 2030 Sustainable Development Goals

Goal 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	By 2030: sustain per capita economic growth in accordance with national circumstances, and in particular at least 7% per annum GDP growth in the least-developed countries; promote development-oriented policies that support productive activities; improve global resource efficiency in consumption and production, and decouple economic growth from environmental degradation, etc.
Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	By 2030: develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure; upgrade infrastructure and retrofit industries to make them sustainable, with increased resource use efficiency; enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, etc.
Goal 10	Reduce inequality within and among countries	By 2030: progressively achieve and sustain income growth of 40% for the bottom of the population at a rate higher than the national average; empower and promote the social, economic and political inclusion of all irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status, etc.
Goal 11	Make cities and human settlement inclusive, safe, resilient and sustainable	By 2030: provide access to safe, affordable, accessible and sustainable transport systems for all; strengthen efforts to protect and safeguard the world's cultural and natural heritage; reduce the adverse per capita environmental impact of cities, etc.
Goal 12	Ensure sustainable consumption and production patterns	By 2030: all countries taking action by implementing the 10-Year Framework of Programmes on sustainable consumption and production (10YFP); achieve sustainable management and efficient use of natural resources; promote public procurement practices that are sustainable in accordance with national policies and priorities, etc.
Goal 13	Take urgent action to combat climate change and its impacts	By 2030: strengthen resilience and adaptive capacity to climate related hazards and natural disasters in all countries; by 2020, mobilize USD100 billion annually from all sources jointly by developed country Parties to the UNFCCC to implement the commitment undertaken to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation, and fully operationalize the Green Climate Fund through its capitalization as soon as possible, etc.

Adapted from SDKP, 2017

### Appendix 3C: Agenda 2030 Sustainable Development Goals

Goal 13	Take urgent action to combat climate change and its impacts	By 2030: strengthen resilience and adaptive capacity to climate related hazards and natural disasters in all countries; by 2020, mobilize USD100 billion annually from all sources jointly by developed country Parties to the UNFCCC to implement the commitment undertaken to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation, and fully operationalize the Green Climate Fund through its capitalization as soon as possible, etc.
Goal 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	By 2025, prevent and significantly reduce marine pollution of all kinds; by 2020, effectively regulate harvesting, and end overfishing, illegal, unreported and unregulated (IUU) fishing and destructive fishing practices and implement science-based management plans; conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on best available scientific information, etc.
Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystem, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity	By 2020: ensure conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services; promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests, and increase afforestation and reforestation by x% globally; combat desertification, and restore degraded land and soil, including land affected by desertification, drought and floods, etc.
Goal 16	Promote peaceful and inclusive society for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	By 2030: significantly reduce all forms of violence and related death rates everywhere; substantially reduce corruption and bribery in all its forms; provide legal identity for all including birth registration; promote and enforce non-discriminatory laws and policies for sustainable development, etc.
Goal 17	Strengthen the means of implementation and revitalize the global partnership for sustainable development	By 2030: strengthen domestic resource mobilization, including through international support to developing countries; developed countries to implement fully their ODA commitments (provide 0.7% of GNI in ODA to developing countries); mobilize additional financial resources for developing countries from multiple sources; assist developing countries in attaining long-term debt sustainability via policies aimed at fostering debt financing, debt relief and debt restructuring.

Adapted from: SDKP, 2017

## Appendix2A: Non-Regulatory and Voluntary Standards

NON-REGULATORY AND VOLUNTARY STANDARDS (1)					
Scheme	Year Developed & Country	Uniqueness	Applications	Methodologies	Sources
BREEAM (BRE Environmental Assessment Method).	1990, by the Building Research Establishment (BRE), UK.	BREEAM is known as the foundation for best practices in sustainable design; and has become the foremost effective scheme globally for the measurement and qualification of environmental performance of buildings.	BREEAM assessment measures building's sustainability against a set of environmental and sustainability criteria. Credits are awarded for each nine categories based on building performance and the total weighting of criteria.  BREEAM has several schemes such as BREEAM UK, BREEAM Europe and BREEAM international. These schemes' operation basics are BREEAM-new construction, BREEAM-in-use for existing buildings.	Benchmark weighted score criteria: such as: management; health and wellbeing; energy; transportation; water; land use and ecology; materials and innovation. A building is awarded environmental performance (either Uncertified, Pass, Good, Very Good, Excellent or Outstanding) based on its total score.	(Cotgrave and Riley, 2013; Tymkow, et al., 2013b); (Alvami and Rezgui, 2012; BREEAM, 2015)
LEED (American's Leadership in Energy and Environmental Design).	August 1998, by the US Green Council for the US Department of Energy.	LEED is the equivalent of the UK's BREEAM as a means of rating green building design.  LEED covers different types of buildings (neighbourhood developments included) based on possible 110 points for each version.	Buildings are sorted into four grades of certifications namely: Certified (40-49 points), Silver (50-59 points), Gold (60-79 degrees) and Platinum (80 points and above).	Its rating systems cover six main areas with disaggregated possible points: energy and atmosphere (36 points), sustainable sites (26 points), indoor environmental quality (15 points), materials and resources (14 points), water efficiency (10 points), and bonus points for innovation in the design process (6 points), and regional priority (4 points).	(Cotgrave and Riley, 2013; Tymkow, et al., 2013b; Foxell, 2014),

## Appendix2B: Non-Regulatory and Voluntary Standards

NON-REGULATORY AND VOLUNTARY STANDARDS Cont'd (2)					
Scheme	Year Dev. & Country	Uniqueness	Applications	Methodologies	Sources
NABER (National Australian Built Environmental Rating Scheme)	Developed by the Australian Government	NABER is a national rating scheme aimed at measuring and comparing the environmental performance of buildings, tenancies and homes in Australia.	It measures the environmental impact of existing buildings over their past performance within last 12 months. The higher the NABERS rating, the better the tangible environmental performance of a building. A 6 star rating demonstrates market-leading performance, whereas 1 star means the building has good potential for improvement	The scheme measures: energy efficiency, water usage, waste management, and indoor environmental quality of a building or tenancy; and its impact on the environment based on star rating scale from 1-star in 6-star	(Tymkow, et al., 2013b; NABERS, 2015).
CASBEE (Comprehensive Assessment System for Building Environmental Efficiency)	2001, developed in Japan by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)	A joint industry/government/academic project. CASBEE is a tool for assessing and rating the environmental performance of buildings and the built environment.	CASBEE tools cover different types of buildings (New construction, existing building, renovation, and homes); and developments (heat island, urban development and cities). Two factors are considered, namely: Q (Quality) - Building Environmental Quality and performance; and L (Loadings) - Building Environmental Loadings	CASBEE deals with four assessment areas (energy efficiency, resource efficiency, local environment and indoor environment); and two spaces (internal and external) are involved. CASBEE defined by hypothetical boundaries (site and other elements).	(Tymkow, et al., 2013; CASBEE, 2015)



## Appendix2C: Non-Regulatory and Voluntary Standards

NON-REGULATORY AND VOLUNTARY STANDARDS Cont'd (3)					
Scheme	Year Dev. & Country	Uniqueness	Applications	Methodologies	Sources
SBTool (Sustainable Built environment Tool formally known as GBTool)	Developed by the International Initiative for Sustainable Built Environment (iSBE) in Canada.	A generic tool for building assessment and the framework, with categories and weighted criteria.  It recognizes the different priorities, technologies, building traditions and cultural values peculiar to the various countries involved in the assessment.	The rating is based on a scoring process structured in four levels, with higher levels obtained from the weighted aggregation of the lower ones, using 1 goal, 7 issues and 29 categories.  All the criteria and sub-criteria are scored based on a linear scale of -2 to +5.	Seven assessment categories with scores and weighted criteria: Site regeneration and development, urban design and infrastructure; Energy and resource consumption; Environmental loading; Indoor environmental quality; Services quality; Social, cultural and perceptual aspects; and Cost & economic. Benchmark and weights are enhanced by national references, using various analytical hierarchy process	(Sballiance, 2015)
PASSIHAUS	Early 1990s by Professors Wang Feist and Bo Adamson of the PassivHaus Institut in Darmstadt, Germany	A German standard for reducing building energy use with special focus on very-low-energy construction standard	PassivHaus standard was specifically designed to reduce the need for space heating and cooling in buildings during operations.	PassivHaus take a fabric-first tactic of using very high insulated envelope (extraordinary airtightness with whole-building mechanical ventilation & heat recovery) requirement	(Cotgrave and Riley, 2013; Foxell, 2014)
Several others: HK-BEAM					

### Appendix3A: UK Government's Actions

UK Government's Actions on Improving Building Sustainability (1)				
Programmes	Year Established	Goals, Objectives & Funding	Activities & Success	Sources
Government's Action Energy (formerly, Energy Efficiency Best Practice Programme)	2002	It was the first UK's leading programme that helped to inspire the take up of EE measures and low carbon technologies by businesses and public sector. Funded by the UK's DEFRA and the Devolved Administrations	Through the Carbon Trust, the programme has carried out the following services free for businesses: 1,100 energy surveys; offers advice and information; offer access to money; and interest free loans for eligible energy efficiency investment projects through its energy efficiency loan scheme. Also, it developed a unique knowledge base and contacts database across industry, commerce and the public sector	(Vincent, 2003).
Government's Enhanced Capital Allowance Scheme (ECAS)	2001	Developed to ensure that the UK meet its domestic target of 20% CO <sub>2</sub> emissions reduction. UK put it in place to encourage business and public sector to invest in low carbon technologies.	ECAs allows businesses to claim 100% as first-year capital allowance for investment in qualifying energy saving technologies such as: boilers, pipe work insulation, low CO <sub>2</sub> emitting cars and refuelling infrastructure (motors and drives), refrigeration equipment, and automatic metering and monitoring equipment against tax.	(Environment and Energy, 2000; Foxell, 2014; Vincent, 2003),
UK's Foundation programme and the Low Carbon Innovation Program (LCIP)	2002	it's aimed at investment of £75 million GBP in encouraging development new and evolving low carbon technologies	It also provided funding for research & Development, demonstration, carbon finance, investments and removal of non-technical barriers to innovation and commercialisation.	(Vincent, 2003).
Feed-in Tariff (FIT)	April 2010	Encourage the deployment of low carbon electricity generations into buildings. excess electricity generated by buildings is supplied to the national grid, and payments are made by vendors for the unit of electricity generated to the building owners	The allowable low carbon technologies are wind turbines, solar photovoltaic (PV), hydro turbines, anaerobic generation up to 5MW and domestic-scale micro-CHP up to 2kW capacities (Foxell, 2014). The scheme exceeded its 3GW of renewable energy capacity with: 568,612 solar PVs; 6,256 micro wind turbines; 546 hydro and 136 anaerobic digestion (FIT installations) across Britain as at 2015.	(Ofgem, 2016).

### Appendix3B: UK Government's Actions

UK Government's Actions on Improving Building Sustainability Cont'd (2)				
Programmes	Year Established	Goals, Objectives & Funding	Activities & Success	Sources
Green Deal	January, 2013. UK government stop funding the GDFC in July 2015, thereby stopped further application for Green Funding.	to stimulate the acceptance of energy-saving measures in buildings (domestic and non-domestic)	The scheme has forty-five listed possible interventions with maximum value of £10,000, which will pay for and provided by the green deal provider. The Green Deal provider recovered their money through attached energy bills, at 7% maximum interest rate. Whereas, the Green Deal Finance Company (GDFC) will lend money to Green Deal providers. It characterised with low uptake by building owners	(Foxell, 2014; Green Deal, 2015).
Renewable Heat Incentive (RHI)	November, 2011 & April, 2014, Domestic Scheme	Government's Cash Back. Provides cashback payments for installation and delivery of renewable heat supplies to buildings (private and public). The scheme is being administered by Ofgem, the Office of Gas and Electricity Market Authority	The payment from the government helps businesses, NGOs and public sector meet the cost of installation of biomass, heat pumps (ground source, water source and air source), solar thermal collectors, bio-methane & gas and CHP systems. The payment is based on the heat output of the installed renewable heat technology and is spread over 20 years	(Renewable Heat Incentive, 2015).
Energy Companies Obligation (ECO)	December, 2012	ECO is a government scheme that compels larger suppliers to provide energy efficiency interventions to domestic buildings. ECO1 covers the period between January 2013-March 2015 and ECO2 runs from April 2015-March 2017.  Finally, in the Home Heating Cost Reduction Obligation, they must encourage the improvement of the ability of low income and vulnerable household to heat homes through replacement or repair of boilers	Under the ECO targets, suppliers have three obligations. The Carbon Emission Obligation, where they must encourage 'primary measures', roof and wall insulation, connections to district heating systems and other 'secondary measures' installed on the same premises.  The Carbon Saving Community Obligation, where suppliers (eleven UK's energy companies) must promote insulation measures and connection to district heating systems in low income areas, using at least 15% of their CSCO in low income, vulnerable and deprived rural areas.	(Ofgem, 2015).



### Appendix3C: UK Government's Actions

UK Government's Actions on Improving Building Sustainability Cont'd (3)				
Programmes	Year Established	Goals, Objectives & Funding	Activities & Success	Sources
UK's Carbon Trust	April 2001, by the UK Government	<p>Carbon Trust focusses its efforts towards contributing to the achievement of: UK's aspiration of 60% carbon dioxide reduction by the middle of this 21st century (by 2050); and, a target of 20% of renewable energy input into UK's total energy supply by 2020, as contained in the UK's Energy White Paper.</p> <p>The Trust has the following set objectives: to ensure that business and the public sector accomplish CO2 emissions targets; enhance the effectiveness of UK business through resource efficiency; and to support the recapitalisation of UK industry sector based on innovation and commercial value of low carbon technologies</p>	<p>A private company set up to help businesses and public organisations reduce their CO<sub>2</sub> emissions.</p> <p>It is partly funded by the Climate Change Levy.</p> <p>It helps to stimulate carbon savings, stimulates investments in low carbon technologies under its low carbon innovative programme, and inform low the low carbon debate.</p> <p>Furthermore, the company have programmes and initiatives such as: Carbon Trust Standard, Energy Action programme, ECA Scheme, and foundation programme&amp; LCIP amongst others to achieve its set goals.</p>	(Vincent, 2003; Foxell, 2014)
UK's Carbon Trust Standard	2006	<p>This is a certification scheme introduced by the Carbon Trust to recognise organisations that have reduced their CO<sub>2</sub> emissions and continue to lower it on a yearly basis. The certification process is based:</p> <p>Manage Reduce Measure Certify</p>	<p>To meet the requirements of the Carbon Trust Standard, organisations must do the following:</p> <ul style="list-style-type: none"> <li>□ Measure their carbon footprint, which include the electricity and gas consumption, on-site fuel consumption, and vehicles' fuel used</li> <li>□ Meet a 25% per annual reduction in carbon efficiency benchmark or meeting an absolute emission reduction</li> <li>□ Show evidence of using standard and approved government procedure in managing carbon, methodology, accurate carbon accounting and management programmes.</li> <li>□ Over 1,000 successful certification have been awarded.</li> </ul>	(Foxell, 2014; Carbon Trust, 2017)

#### Appendix4A: Low-Zero Carbon Energy Sources

LOW-ZERO CARBON ENERGY SOURCES (1)				
Energy Sources	Application Context	Material Composition & Types	Efficiency & Sizes	Cost
Solar PV panels	<p>Solar energy is the heart of all forms of REN systems as the source of energy and lives on earth. The sun's radiant energy provides direct heat and light to buildings; and provides source of heating, hot water or steam for industrial processes and electrical generation, (Bahaj, 2005).</p> <p>There is differential penetration and uneven spread of solar radiation through the upper atmosphere and the earth's surface, respectively, depending on latitude and cloud cover, (Tymkow, et al., 2013b). Hence, the resultant average net incoming radiation from the planet is 240W/m<sup>2</sup>, which varies depending on location. The average accumulated radiation over a time is required in determining the potential viability of a photovoltaic panel (PV) generation (Coley, 2008; Tymkow, et al., 2013b).</p>	<p>Solar PV is made of a semiconductor that absorb energy (sunlight) and converts it into electricity directly. The solar cell (PV) uses 'photovoltaic effect' of absorbing the energy from the sun and convert it into a current that flow between two opposites charged semiconductor layers.</p> <p>These layers converts sunlight into electricity; and can generate power from watts to megawatts and could be integrated within the building envelope (Bahaj, 2005).</p> <p>Several studies (Bahaj, 2005; Mhalas, 2013; Szokolay, 2014), have confirmed that solar PV are mostly in two differently doped crystals of silicon cell; and building integrated PV (BiPV), has become a common practice. Solar PV could be in the form of: single crystal or monocrystalline (grown as a cylinder and sliced into thin wafers), that are considered more efficient, reliable and relatively expensive; or poly-crystalline that are made from several crystals, but less efficient and more economical; and or the amorphous silicon, which is made with thin-film cells that are more expensive with lower efficiency.</p>	<p>The size of a solar PV is rated in peak power output, (Watt, peak, Wp) under standard irradiance. (Szokolay, 2014). The efficiency, annual energy yield and cost of a typical PV varies depending on its manufactured materials. Mhalas (Mhalas, 2013), classified these into first generation: monocrystalline silicon (15%-23% efficiency and 710-790kWh /kWpk); polycrystalline silicon (8%-15.5% efficiency and 690-800kWh /kWpk); and heterojunction with intrinsic thin layer (16-23% efficiency and up to 750kWh /kWpk).</p> <p>While, the second generation PVs are: Amorphous silicon (4-10.5% efficiency and 620-900 kWh /kWpk); Cadmium Telluride (7-11% efficiency and 560-760kWh /kWpk); and Copper Indium and Gallium (9-13.5% efficiency and 820-1000 kWh /kWpk).</p>	<p>The cost of solar PVs and installation in the UK is about £5,000-£9,000 depending on the panel type and the size of the modules. Also, it is eligible for feed-in-tariff at the current rate of £0.154/kWh and export tariff of £0.045/kWh, (Mhalas, 2013).</p> <p>PV technology has 1-3years payback period; and a 1000kWh electricity generated from PVs save about 0.43 tons of CO<sub>2</sub> emissions (Bahaj, 2005), hence it serve as a measure for BEP improvement for Nigeria and UK.</p>

#### Appendix4B: Low-Zero Carbon Energy Sources

##### LOW-ZERO CARBON ENERGY SOURCES Cont'd (2)

Energy Sources	Application Context	Material Composition & Types	Efficiency & Sizes	Cost
Solar thermal	Solar thermal is another REN technology that has been advanced as a veritable intervention for buildings in extant literatures (Tymkow, et al., 2013a; Szokolay, 2014). The technology is based on the concept of heating water indirectly from the sun. Heat energy from the sun is collected through absorption by the black surface of solar collectors.	<p>The technology usually transformed solar radiation from the sun into thermal energy. A thermal fluid inside the plate absorbs and transmits heat from the collector plate to the storage tank. The heated water is used for domestic hot water, space heating and process heating. The absorber plates are often coated selectively to improve efficiency; and are manufactured in either non-concentrating solar collectors or concentrating solar collectors.</p> <p>The non-concentrating solar collectors are used for domestic buildings where low temperature water, space and process heating are required. Whereas, concentrating solar collectors use reflectors to concentrate solar energy into the absorbers. They are used for high temperature requirement, especially industrial applications, district heating and power generation. The flat plate collectors can heat water or air to over 90°C, while much higher temperatures can be obtained by using concentrating collectors (Szokolay, 2014).</p>	<p>Solar thermal panels are now available in modules form, size ranging from 4-8m<sup>2</sup> of panels or tubes with hot water capacity up to 100kWh/year.</p> <p>Solar thermal panels are now available in modules form, size ranging from 4-8m<sup>2</sup> of panels or tubes with hot water capacity up to 100kWh/year (Tymkow, 2013)..</p>	<p>A solar thermal system has 20-25years life span with low maintenance cost, and annual operating plus maintenance cost of 1% of the investment. The price for field collectors used for district heating and industrial process heat is about £175/m<sup>2</sup>, (Tymkow, 2013).</p> <p>They cost £5,000-8,000 including installation and plumbing, depending on the type and numbers of modules (Mhalas, 2013).</p>

#### Appendix4C: Low-Zero Carbon Energy Sources

##### LOW-ZERO CARBON ENERGY SOURCES Cont'd (3)

Energy Sources	Application Context	Material Composition & Types	Efficiency & Sizes	Cost
Wind Turbines	<p>Some authors (Tymkow, et al., 2013a; Szokolay, 2014), have confirmed that wind has greater potential as a REN source. Wind power is a form of kinetic energy with potentially much higher power density than solar irradiance.</p> <p>The wind pattern depends on geographical location, elevation and terrain with mean wind speed of 6.5- 7.5m/s at 50m above the ground for most countries.</p>	<p>Wind turbines are classified into two basic types: devices with a horizontal axis and vertical axis. The various blade sizes, power rating and minimum wind speed required are in: 1.1m (has 0.4kW and requires 2.0m/s); 2.1m (has 1.5kW and requires 2.4m/s); 3.5m (has 2.5kW and requires 3.0m/s); 5.4m (has 5.4kW and requires 3.0m/s); 5.5m (has 6.0kW and requires 2.5m/s); and 5.6m (has 6.0kW and requires 2.7m/s).</p> <p>The world's total installed capacity of wind turbines has multiplied since 2000- 2006, and has tripled thereafter. It increased from 1MW in 1980 to almost 203,000MW (203GW) in 2011 (Szokolay, 2014).</p>	<p>Micro-wind turbines for buildings present great potentials for next energy generation. They (<math>\mu</math>-wind turbines) are those with swept area less than 25m<sup>2</sup> and power output &lt;0.5kWp. The <math>\mu</math>-wind turbines have historical applications for off-grid battery charging in sailing boats, and is a <u>recognised</u> technology in the UK.</p> <p>The UK is estimated to have more than 40% of Europe's land-based wind energy potential; and currently ranked world's 6th wind energy producer with over 8GW generation capacity (<u>Mhalas</u>, 2013).</p>	<p>In the UK, installed cost of micro-turbine is between £2,000 (roof mounted) to £22,000 (pole mounted) with 15-23 year life span. The electricity from <math>\mu</math>-wind turbines is also eligible for feed-in-tariff at £0.1544/kWh and export rate of £0.045/kWh (<u>Mhalas</u>, 2013).</p> <p>Like solar PV panels, micro-turbines offer great potential as an improvement measure for BEP especially existing stocks.</p>

#### Appendix4D: Low-Zero Carbon Energy Sources

LOW-ZERO CARBON ENERGY SOURCES Cont'd (4)

Energy Sources	Application Context	Material Composition & Types	Efficiency & Sizes	Cost
Hydro-Turbines	Electricity from hydro-turbines are based on water-driven turbines using the forces of falling water from high-level topography or fast-flowing streams. Hydro-turbines have the potentials to provide both power storage capacity and an operating reserve to meet energy demand Foxell, 2014).		Small-scale hydro turbines can be used to provide electricity for specific projects (commercial/ industrial <u>centres</u> with several buildings, small estates, remote locations, village etc.) (Foxell, 2014)	N/A
Biomass Boiler Technology	Bioenergy consist of different energy sources that relies on various forms of organic matter. The technology is used for generating heat in buildings and industrial purposes (Foxell, 2014).	It is based on the combustion of waste timbers, forestry and park maintenance and energy crops like miscanthus and switch grass (Foxell, 2014).	The boiler is self-igniting and regulating and operates at over 90% efficiency. The size of biomass ranges from large domestic capacity (10Kw or less) to industrial or community use (5MW plus) (Foxell, 2014).	N/A

#### Appendix4E: Low-Zero Carbon Energy Sources

LOW-ZERO CARBON ENERGY SOURCES Cont'd (5)

Energy Sources	Application Context	Material Composition & Types	Efficiency & Sizes	Cost
Fabric Change	<p>Fabric insulations (double fabric, smart facades, double and triple glazing, and low-e glazing), are low carbon interventions for existing buildings' retrofit. Fabric change to smart-facades (climatic envelope), could aid save energy use and improve comfort in existing buildings (<a href="#">Kahararachchi, et al., 2005</a>).</p> <p>Whilst, the U-value and solar heat gain coefficient of window have great impacts on the heating and cooling loads of a building (<a href="#">Ahn, et al., 2016</a>).</p> <p>A past study (<a href="#">Ignjatović, et al., 2012</a>), that used the EnergyPlus simulation programme, revealed that addition of double skin facades resulted in heating energy savings of about 55.8%; <u>at the proper glazing to</u> increase in cooling energy if proper glazing is not properly selected.</p>	Envelope insulation to wall, roof and floor; double/ triple glazing; double facade	<p>Also, envelope insulation to wall, ceiling and floor have resulted in significant energy savings up to 35.0% (<a href="#">Altan, 2010</a>), and improved indoor comfort performance. Whilst, insulation and air tightness reduce heat loss during winter season, but do lead to overheating during summer seasons (<a href="#">Lee, et al., 2016</a>).</p> <p>Whilst, the U-value and solar heat gain coefficient of window have great impacts on the heating and cooling loads of a building (<a href="#">Ahn, et al., 2016</a>). These past studies indicated that the cooling energy increases with internal heat gain; and with increased in thermal insulation performance. Consequently, constant fabric improvement is the potential intervention for commercial buildings in the UK;</p>	N/A



#### Appendix4F: Low-Zero Carbon Energy Sources

LOW-ZERO CARBON ENERGY SOURCES Cont'd (6)

Energy Sources	Application Context	Material Composition & Types	Efficiency & Sizes	Cost
LEDs	Light-emitting diodes, lighting sensors and automated switch-off systems are commonly being used as energy efficient lighting worldwide.	Sensors, thermostat, automatic switch-off, compact florescence lamps etc.	<p>A past study (Li, et al., 2010), shows predicted energy savings when low energy luminaires and high-dimming photoelectric control were used in buildings.</p> <p>Also, the use of compact fluorescence lamps (CFL) along with other EE interventions: raising thermostat set point for air conditioners, application of advance glazing, insulation and reduction of energy intensity can save up to 77,569MWh of energy use in office buildings in Malaysia (<a href="#">Saidur, 2009</a>). Similar interventions are considered appropriate for Nigeria.</p>	N/A

## Appendix5: Operational Sustainability Tool- OST

Primary Indexes	Primary Indicators (Indices)	OS Measurement Tool for Case Buildings: Likert's Scale of -2 to +2									
		B101	B101	B103	B104	B105	B206	B207	B208	B209	B210
Climate	Mitigation Policy										
	Adaption Measures										
	Comfort										
Mgt- Policy	CIEs										
	SSP										
	SFM										
	SEM										
	BAM										
	Edu. /Train. on EE										
Operational	Assmnt. / Benchmark										
	Energy Modelling										
	Reg. Energy Audit										
	Eff. Lighting/ Equip.										
	HVAC matching										
	BMS, BEMs Tech.										
	LZC solutions										
	Envelop Insulation										
	HVAC Efficiency										
	BCT										
	Main. / Retrofit										
Reg. Policy	Reg. Framework										
	Codes/ Stand.										
	Energy Certification										
Bus. Practices	Poor Supply Chain										
	Corruption										
	CSR										
Primary Indexes	Primary Indicators (Indices)	OS Measurement Tool for Case Buildings: Likert's Scale of -2 to +2									
		B101	B101	B103	B104	B105	B206	B207	B208	B209	B210
Culture	Environ. Norms										
	Attitude										
	Habit										
	Intention										
	Behaviour										
	Info. Awareness										
	BCT										
LZC Intervention	Solar PV										
	MWT										
	CHP										
	Solar Thermal										
	LEDs										
	Inverter										
	GSHP										
Barrier/Driver											
Barriers	Lack (L.) of Policy										
	L. Code/Standard										
	L. Skills										
	Political Unrest										
	Electricity Supply										
	Behav.& style										
	Incomp. Inform										
	Asset Value										
	Market Force										
Strategic Drivers	SSP/SFM										
	SEM										
	PMs/KPIs										
	BEMTechs										
	TEBP										
	RETOS										
	BCT										
PMs/KPIs	BEU										
	BEUI										
	BCo <sub>2</sub> Emission										
	BCo <sub>2</sub> Intensity										
	BEC- Energy Cost										
	BECI- intensity										

Source: Study Author 2016



## Appendix6: OS Toolkit Weighting Scale Summary

Likert's Scale	+2	+1	0	-1	-2
Organisation Policy	Written Policy + Practice	Written + Not practice	Planned Policy + Planned Practice	Unwritten Policy + Not Practice + Aware	Unwritten Policy + Unaware
Organisation's Practices	Strongly Active	Active	Neutral	Passive	Strongly Passive
Government Policy	Existence + Effective	Existence	Not-in-Existence + Planned	Not-in-Existence + Unplanned + Aware	Not-in-Existence + Unaware
Installations	Installed + Effectively Working	Installed + Working	Planned Installation	Unplanned Installation	Unplanned + Unaware
Behaviour (Organisation/ Users)	Very Good	Good	Neutral	Poor	Very Poor

## Appendix7: OST Weighting Scale Application

OPERATIONAL SUSTAINABILITY TOOL KIT- Physical Survey Sheet1								
OS Measurement Tool for Case Buildings: Likert's Scale of -2 to +2								
S	Prim. Indexes	Primary Indicators	Grouping	-2	-1	0	1	2
A	Climate Change							
1		Mitigation Policy	Org. Policy	Absence, Not Practice & Unaware	Absence, Not Practice but Aware	Planning for Policy + Practice	Written Policy + No Practice	Written Policy + Practice
2		Adaption Measures	Org. Policy	Absence, Not Practice & Unaware	Absence, Not Practice but Aware	Planning for Policy + Practice	Written Policy + No Practice	Written Policy + Practice
3		Comfort	Org. Practice	Strongly Passive	Passive	Neutral	Active	Strongly Active
B	Mgt. Policy							
4		CIEs	Org. Policy	Absence, Not Practice & Unaware	Absence, Not Practice but Aware	Planning for Policy + Practice	Written Policy + No Practice	Written Policy + Practice
5		SSP	Org. Policy	ditto	ditto	ditto	ditto	ditto
6		SFM	Org. Policy	ditto	ditto	ditto	ditto	ditto
7		SEM	Org. Policy	ditto	ditto	ditto	ditto	ditto
8		BAM	Org. Policy	ditto	ditto	ditto	ditto	ditto
9		Edu. /Train. on EE	Org. Policy	ditto	ditto	ditto	ditto	ditto
C	Operational FM							
10		Assmnt. / Benchmark	Org. Practice	Strongly Passive	Passive	Neutral	Active	Strongly Active
11		Energy Modelling	Org. Practice	ditto	ditto	ditto	ditto	ditto
12		Reg. Energy Audit	Org. Practice	ditto	ditto	ditto	ditto	ditto
13		Eff. Lighting/ Equip.	Org. Practice	ditto	ditto	ditto	ditto	ditto
14		HVAC matching	Org. Practice	ditto	ditto	ditto	ditto	ditto
15		BMS, BEMs Tech.	Installation	Unplanned + Unaware	Unplanned Installation	Planned Installation	Installed + Working	Installed + Effectively Working
16		LZC solutions	Installation	ditto	ditto	ditto	ditto	ditto
17		Envelop Insulation	Installation	ditto	ditto	ditto	ditto	ditto
18		HVAC Efficiency	Installation	ditto	ditto	ditto	ditto	ditto
20		BCT	Org. Practice	Strongly Passive	Passive	Neutral	Active	Strongly Active
21		Main. / Retrofit	Org. Practice	Strongly Passive	Passive	Neutral	Active	Strongly Active
D	Regulatory Policy							
22		Regulatory Framework	Govt. Policy	Absence + Unaware	Absence + Unplanned + Aware	Absence + Planned	Existence	Existence + Effective
23		Codes/ Standards	Govt. Policy	ditto	ditto	ditto	ditto	ditto
24		Energy Certification	Govt. Policy	ditto	ditto	ditto	ditto	ditto
E	Bus. Practice							
25		Poor Supply Chain	Org. Practice	Strongly Passive	Passive	Neutral	Active	Strongly Active
26		Corruption	Org. Policy	Absence, Not Practice & Unaware	Absence, Not Practice but Aware	Planning for Policy + Practice	Written Policy + No Practice	Written Policy + Practice
27		CSR	Org. Policy	Absence, Not Practice & Unaware	Absence, Not Practice but Aware	Planning for Policy + Practice	Written Policy + No Practice	Written Policy + Practice
OST- SHEET1 SUB-TOTAL TO SUMMARY SHEET2								
OPERATIONAL SUSTAINABILITY TOOL KIT- Physical Survey Sheet2								
OS Measurement Tool for Case Buildings: Likert's Scale of -2 to +2								
SN	Primary Indexes	Primary Indicators	Grouping					
F	Energy Culture							
28		Environ. Norms	Behaviour	Very Poor	Poor	Neutral	Good	Very Good
29		Attitude	Behaviour	ditto	ditto	ditto	ditto	ditto
30		Habit	Behaviour	ditto	ditto	ditto	ditto	ditto
31		Intention	Behaviour	ditto	ditto	ditto	ditto	ditto
32		Behaviour	Behaviour	ditto	ditto	ditto	ditto	ditto
33		Info. Awareness	Org. Practice	Strongly Passive	Passive	Neutral	Active	Strongly Active
34		BCT	Org. Policy	Absence, Not Practice & Unaware	Absence, Not Practice but Aware	Planning for Policy + Practice	Written Policy + No Practice	Written Policy + Practice
G	LZC Intervention							
35		Solar PV	Installation	Unplanned + Unaware	Unplanned Installation	Planned Installation	Installed + Working	Installed + Effectively Working
36		MWT	Installation	ditto	ditto	ditto	ditto	ditto
37		CHP	Installation	ditto	ditto	ditto	ditto	ditto
38		Solar Thermal	Installation	ditto	ditto	ditto	ditto	ditto
39		LEDs	Installation	ditto	ditto	ditto	ditto	ditto
40		Inverter	Installation	ditto	ditto	ditto	ditto	ditto
41		GSHP	Installation	ditto	ditto	ditto	ditto	ditto
H	Barrier/Driver							
	Barriers	Lack of Policy/Framework	Govt. Policy	Absence + Unaware	Absence + Unplanned + Aware	Absence + Planned	Existence	Existence + Effective
42		Lack of Code/Standard	Govt. Policy	ditto	ditto	ditto	ditto	ditto
43		Lack of Skills	Govt. Policy	ditto	ditto	ditto	ditto	ditto
44		Political Unrest	Govt. Policy	ditto	ditto	ditto	ditto	ditto
45		Electricity Supply	Govt. Policy	ditto	ditto	ditto	ditto	ditto
46		Inefficient Behav.& style	Org. Practice	Strongly Passive	Passive	Neutral	Active	Strongly Active
47		Incomp. Inform	Org. Practice	Strongly Passive	Passive	Neutral	Active	Strongly Active
48	Strategic Drivers	Asset Value	Org. Policy	Absence, Not Practice & Unaware	Absence, Not Practice but Aware	Planning for Policy + Practice	Written Policy + No Practice	Written Policy + Practice
49		Market Force	Org. Policy	Absence, Not Practice & Unaware	Absence, Not Practice but Aware	Planning for Policy + Practice	Written Policy + No Practice	Written Policy + Practice
50		SSP/SFM	Org. Practice	Strongly Passive	Passive	Neutral	Active	Strongly Active
51		SEM	Org. Practice	ditto	ditto	ditto	ditto	ditto
52		PMs/KPIs	Org. Practice	ditto	ditto	ditto	ditto	ditto
53		BEMTechs	Org. Practice	ditto	ditto	ditto	ditto	ditto
54		TEBP	Org. Practice	ditto	ditto	ditto	ditto	ditto
55		RETOS	Org. Practice	ditto	ditto	ditto	ditto	ditto
56		BCT	Org. Practice	ditto	ditto	ditto	ditto	ditto
OST- SHEET2 SUB-TOTAL				0				
OST- % SCORE BASED ON OVERALL WEIGHTING				0				

Source: Study Author 2016

### Appendix8A: SEQM Analytic Procedure

Structural Equation Modelling Analytic Techniques- Protocol (Blunch, 2008) (1)	
Procedure	Review/ Explanation of the Procedure Undertaken
1. Missing Data: Case and Variable Screening	<p>The validation study dataset from 120 respondents was screened for missing data. Missing values were handled with the use of IBM SPSS 20 via multiple imputation for missing data. The technique simply replaced missing values with the mean of all the variables (Blunch, 2008). The result indicated 9.94% (about 10.0%) overall missing data for all the variables, which is within the maximum allowable threshold. Generally, the percentages of missing data vary amongst variables (~ 100.0%), cases (~ 45.8%) and values (~19.9%). However, the dataset's missing value meets the upper threshold of missing responses not greater than 10.0%, as a value greater than this could lead to bias (Lowry and Gaskin, 2014).</p> <p>Missing values were analysed for patterns to determine whether it is systematic or random. Twenty-five iterations were performed and a best fit for all missing values was achieved for the study's 120 sample size. The hypothesis that the study's data are not missing randomly is tested using MCAR test. The little's MCAR test Chi-Square (~ 1539.455; significant ~ .182 &gt; .05) was obtained. MCAR test indicated a non-significant p-value &gt; .05, hence the missing value indicate minor tenancy shown that all missing values are missing randomly (Sen, Roy and Pal, 2015); (Armstrong and Overton, 1977). The MCMC estimation was used for replacing missing values with absolute means.</p>
2. SEM Descriptive Statistics	<p>The Reliability of sampled data depends on the sample size (Kline, 1998; <u>Jenatabadi and Ismail, 2014</u>); thus, reliability of estimate for the screened data was considered. However, <u>Jenatabadi and Ismail (2014)</u>, believe that studies with a sample size of less than 100 are considered low in degree of reliability; while those having 100-200 cases are considered to have an average degree of reliability; and those with more than 200 cases are viewed to have a high degree of reliability. The current study has a sample size of 120, which fall in the category of the average degree of reliability.</p> <p>Detection of outliers was not necessary for most variables were surveyed with 5-point Likert's scale. It has been confirmed that answering extreme with Likert's scale (1 or 5) could not be a representative of an outlier behaviour (Gaskin, 2012). However, two variables: strategic management of building with its nine indicators (measured with 3-point Likert scale); and the group identity variable (location) (measured with 2-point scale), were measured with different scales.</p> <p>The normality issues for the dataset was also considered. The normality test via SEM is based on the values of skewedness and kurtosis. The endogenous variables normality was accepted when the absolute kurtosis is less than 7 (&lt; 7) and the value of skewedness is between -2 and +2. Controlling for outliers and maintaining the normal distribution help to control the heterogeneity of the data (Byrne, 2010).</p>

### Appendix8B: SEQM Analytic Procedure

	<p>This very important as it is assumed that all data are normally distributed across all variables, which is not always the case (Gaskin, 2012).</p> <p>Almost all the study variables data are normally distributed, except the SBM measured (3-point scale), and location variable (2-point scale). They both have positive kurtosis greater than <math>+2.00</math>; and their kurtosis value is <math>&gt;</math> three times the value of their standard errors. Although, all study variable's kurtosis values range from <math>-0.81</math> to <math>+5.322</math>, their absolute kurtosis is <math>&lt; 7.0</math> (Byrne, 2010). However, these two variables with ordinal Likert's scale other than 5-point were excluded from the analysis.</p> <p>Whilst, the skewedness for the all other variables lies between <math>-2</math> and <math>+2</math>; and are negatively skewed <math>\sim</math> value ranges from <math>-0.235</math> to <math>-1.280</math>. The standard rule of thumb (Byrne, 2010; <u>Jenatabadi</u> and Ismail, 2014), is that skewedness value should be within <math>-2</math> to <math>+2</math> range; and absolute kurtosis should be less than <math>7.0</math> for the endogenous variable normality test to be accepted. The study's overall variables absolute kurtosis is less than <math>7</math>; and the absolute skewedness is less than <math>+2.0</math>, therefore the normality for endogenous is acceptable and normality is fulfilled (Byrne, 2010).</p>
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### Appendix8C: SEQM Analytic Procedure

Structural Equation Modelling Analytic Techniques- Protocol (Blunch, 2008) Cont'd (2)	
Procedure	Review/ Explanation of the Procedure Undertaken
3. Exploratory Factor Analysis	Exploratory factor analysis (EFA) is used to identify individual factors that can be used to represent relationship amongst sets of study multiple interrelated variables (Chan, et al., 2010). The variables were subjected to factors' reduction using the IBM SPSS 22. Blunch (2008) upheld that EFA could be applied, where the original variables are considered to be indicators of underlying dimension called factors. The appropriateness of the model was examined before using these factors in these models.
4. Choice of Extraction Method for EFA.	<p>The use of SEM for this study aimed to find out amongst others, the significance of correlation between different variables of hypothetical structures. Hence, the need for the appropriate extraction methods becomes very important. Several past studies have illustrated the difference between principal component analysis (PCA), principal axis factoring (PAF), and maximum likelihood (ML). In particular, Gaskin (2012), explained that PCA reflects all the common and unique variances; PAF consider only common variances; and ML make best use of differences between factors and provide model best fit estimate.</p> <p>Current study used the ML factoring method as it provided the variances between all factors and best fit for models. This concur with Blunch (2008) and Gaskins (2012) views; who opined that it is better to use ML for EFA, since it is the method used in AMOS software for CFA and SEM.</p>
5. Sampling Adequacy Test	<p>The study measured the appropriateness of variables grouping into smaller underlying constructs. The rule of thumb for sampling adequacy in establishing variables' relationship was applied using KMO test and Bartlett's test of Sphericity. The Kaiser-Meyer-Olkin measure of sampling adequacy and the Bartlett's test of Sphericity at <math>&lt; .05</math> significance is used in testing study's factors (Fox and Skitmore, 2007; Chan, et al., 2010). A KMO statistics value ranges between 0 and 1, for which a value close to 1 indicates that the patterns of correlations are relatively compact, and FA would yield distinct and reliable individual factor (Field, 2013). The acceptable level of KMO is a threshold <math>&gt; .50</math> (Field, 2013).</p> <p>Whereas, the Bartlett's test of Sphericity reinforces the appropriateness of FA for the study models. It is used in examining the correlations amongst the variables. Chan, et al., claims it is reliable and appropriate when the value of test statistic for Sphericity is large, and the affiliated significance level is small, then the population correlation matrix is an identity matrix. This hold as it is opposed to the concept that correlation matrix is an identity matrix (Chan, et al., 2010).</p> <p>All study sampled variables KMO tests lied within 0.7 and 0.9. The acceptable minimum KMO test is 0.50; value 0.7 and 0.80 is good; and 0.9 and above is great. Whilst, the Bartlett's test of Sphericity must be significant, and current study sampled tests were significance at 0.000 (Sen, Roy and Pal, 2015; Chou, et al., 2015).</p>

### Appendix8D: SEQM Analytic Procedure

#### Structural Equation Modelling Analytic Techniques- Protocol (Blunch, 2008) Cont'd (3)

Procedure	Review/ Explanation of the Procedure Undertaken
6. Test for Reliability	<p>Additionally, alpha reliability test is used for study's variables based on identified pattern matrix. Cronbach's alpha reliability is performed for the extracted factors. The Cronbach's alpha co-efficiency, measured the internal consistency and reliability including the provision of average correlation of all the indicators for a factor (construct) (Chou, et al., 2015).</p> <p>The Cronbach's <math>\alpha</math> must be <math>&gt; 0.70</math> for the scale to be reliable (Chan, et al., 2010). A conservative Cronbach's alpha threshold limit of <math>&gt;</math> than or equal to 0.70 was imposed (Kline, 1998; Lowry, Gaskin and Moody, 2015). The coefficient of reliability (<math>\alpha</math>), is used as indices of measurement of reliability. It is used in comparing reliability of measured indicators as thus (Hair, et al., 2010; Chou, et al., 2015):</p> $Cronbach's \alpha = \frac{k}{k-1} \left( 1 - \frac{\sum_i s_i^2}{s^2} \right) \dots\dots\dots \text{Equation 11}$ <p>In the indices, <math>s_i^2</math> is the variance in each indicator; <math>s^2</math> represent the total variances for the measured indicators; and k is the number of indicators for each construct. Alpha is the <u>ratio</u> of the two variances and its value is between 0 and 1.</p>

## Appendix8E: SEQM Analytic Procedure

### Structural Equation Modelling Analytic Techniques- Protocol (Blunch, 2008) Cont'd (4)

Procedure	Review/ Explanation of the Procedure Undertaken
7. Test for Factorial Validity: Convergent and Discriminate Validity	<p>Factorial validity was established through convergent and discriminant validity (Lowry, Gaskin and Moody, 2015). The assumption that all measured items should be related was tested to know if they actually are related under a given construct. Convergent validity was used to ascertain if factors for a construct are related and their reflection of a construct converge. The factor loadings (FLs) are the correlation between the observed variables and respective constructs (Chou, et al., 2015). The average variance extracted (AVE) and the composite or construct reliability (CR) were used in establishing convergent validity.</p> <p>The AVE is the measure of the variance captured by a construct in relation to the variance due to random measurement error (Sen, Roy and Pal, 2015). It is derived as the mean extracted variance of the indicator loadings for a construct, which <u>summarise</u> the index of convergence (Chou, et al., 2015).</p> <p>It can be calculated (Hair, et al., 2010; Chou, et al., 2015; (Sen, Roy and Pal, 2015) as follows:</p> $AVE = \frac{\sum_{i=1}^n \lambda_i^2}{n} \dots\dots\dots \text{Equation 12}$ <p>Where <math>\lambda</math> is the standardised factor loadings for each construct's indicator and n represent the numbers of items. The correlation between measured observed variables and their respective construct is indicated by the factor loading. The acceptable FL estimate ranges from 0.50 to 1.0; and a variance of 0.50 or higher indicates adequate convergence (Chou, et al., 2015).</p>



### Appendix8F: SEQM Analytic Procedure

The composite reliability (CR), measures the overall internal consistency of indicators to a constructs. It is the reliability of a collection of heterogeneous but similar variables, which is expressed by the formula below based standard notation (Hair, et al., 2010; Chou, et al., 2015; (Sen, Roy and Pal, 2015), :

$$CR = \frac{\left( \sum_{i=1}^n \lambda_i \right)^2}{\left( \sum_{i=1}^n \lambda_i \right)^2 + \left( \sum_{i=1}^n \delta_i \right)^2} \dots\dots\dots \text{Equation13}$$

Where  $\lambda$  is the standardised factor loadings;  $\delta$  represent the error variance; and n represent the numbers of items. CR is derived by squaring the sum of the factor loadings ( $\lambda_i$ ) for each construct and the sum of the error variance terms ( $\delta_i$ ). A CR (R<sup>2</sup>) values between 0.50 and 0.70 is acceptable as the moderate standard (Hair, et al., 2010). It reveals how much of the variance can be explained by the study variables.

Whilst, discriminant validity involves ascertaining that those factors that are not supposed to be associated, are not associated. Also indicates that the correlation matrix shows no correlation is more than 0.70; FLs must be  $\leq 0.70$ ; and there should be no problematic cross loading (Gaskin, 2012).



### Appendix8G: SEQM Analytic Procedure

Structural Equation Modelling Analytic Techniques- Protocol (Blunch, 2008) Cont'd (5)	
Procedure	Review/ Explanation of the Procedure Undertaken
8. Common Method Bias Test	<p>The study established common-methods bias (“mono-method bias”) for variables’ EFA and CFA. This is to ensure that a negative factor is not included in the remaining data for the analysis (Lowry, Gaskin and Moody, 2015). The correlation matrix for constructs in measurement and SEM models were checked in ensuring that none was above 0.90. A correlation above 0.90 is an evidence that there might be a common-method bias. All study constructs’ correlation matrix’s values were below the upper limit of 0.90 (Pavlou, Liang and Xue, 2007; Lowry, Gaskin and Moody, 2015). Hence, common method bias might not likely be a serious concerns in current study’s models.</p>
9. Measurement Models: Confirmatory Factor Analysis	<p>The study used Maximum likelihood (ML) method to test for full SEM; and the application of confirmatory factor analysis (CFA) procedure for study measurement models. The CFA is used to determine the degree of model fit, and overcome the gap of the fitted model with modification indices (MI) (Jenatabadi and Ismail, 2014); (Zhang, et al., 2014). Several studies (Blunch, 2008; Le Dang, et al., 2014; Jenatabadi and Ismail, 2014; Hou, et al., 2014; (Zhang, et al., 2014); etc.), have suggested procedure and the various tests required for an acceptable and compactible model fit. Hence, current study assumed the following procedure for conducting all CFA models.</p> <p>The construct of various energy reducing drivers and solutions were specified, and their indicator variables arrayed. The IBM AMOS 23 graphics was used in carrying out model specification based on the pattern matrix derived from exploratory factor analysis via IBM SPSS20. Subsequently, the model variables (observed, unobserved, endogenous and exogenous), were identified, and the maximum likelihood estimation was performed with modification indices. Two ML estimations were run for study models. The first stage was the evaluation of the validity of the measurement model based on CFA. Whilst the second stage was the testing of the structural model (Le Dang, et al., 2014).</p> <p>In current study’s CFA, manifest variable are connected with pre-specified latent variables. The implication being that every manifest very is an indicator for only one factor. Also, some parameters are constrained to certain value or to have same value with other parameters.</p>

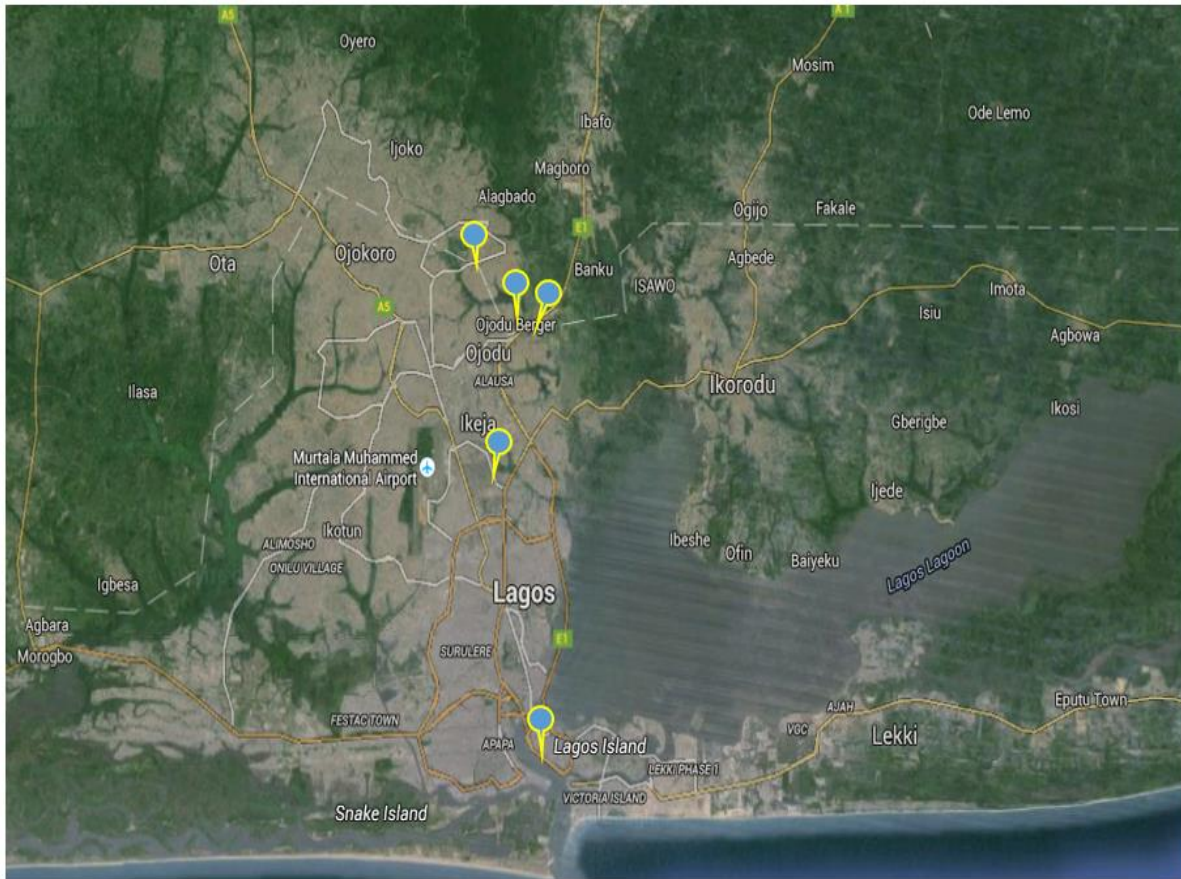
## Appendix8H: SEQM Analytic Procedure

10. Model Fit Indices	<p>The two acceptable criteria required for a valid model fit were used in this study. The measurement model validity level of Goodness-of-fit (GOF); and construct validity were applied (Hair, et al., 2010). Some authors classified the GOF into four namely (Le Dang, et al., 2014): Chi-square test; the absolute fit (baseline fit measure); incremental fit indices; and parsimonious fit indices. The rule of thumb is to use Chi-square and at least one index from each other group (Hair, et al., 2010).</p> <p>Whilst, Blunch (2008), affirms that fit indices are various techniques used in expressing the distance between the sample covariance matrix <math>S</math> and the estimated implied covariance matrix <math>\Sigma(\theta)</math>, which is a function of residual matrix <math>S - \Sigma(\theta)</math>. He however, gave instances of the various techniques based on the use of IBM SPSS AMOSS 22 measures of fit as follows:</p> <p>□ The absolute fit tests are: model <math>\chi^2</math> test (p value <math>&gt; .05</math>) indicating good fit. It can also be CMIN, the minimum value of <math>C</math> (<math>C = [n-1] F</math>), where <math>F</math> is the fit function to be <u>minimised</u> and CMIN is the end result of the <u>minimisation</u> process; and CMIN/DF <math>\sim</math> close to 1.0 is a good fit. Others include: Goodness-of-Fit index (GFI) <math>\sim</math> value between 0 and 1, with value <math>&gt; .95</math> is a good fit; Adjusted goodness-of-fit index (AGFI) have value between 0 and 1, but <math>\sim &gt; .95</math> is acceptable; and RMR usually calculated manually, however RMR (based on correlations) <math>&lt; .05</math> is a good fit (Blunch, 2008).</p> <p>□ The relative fit measures include: Comparative fit index (CFI) <math>\sim</math> value <math>&gt; .95</math> is acceptable; Normed fit index (NFI) with a value <math>&gt; .90</math> is acceptable; Relative fit index (RFI) <math>\sim</math> value <math>&gt; .90</math> is acceptable; Incremental fit index (IFI) <math>\sim</math> value <math>&gt; .90</math> is acceptable; and Tucker Lewis index (TLI) (Tucker and Lewis, 1973) <math>\sim</math> close to 1.0 is a good fit (Blunch, 2008).</p> <p>□ The parsimony fit measures include: PRATIO, which is the factor by which you can modify fit indices to take account of parsimony (James, <u>Mulaik</u> and Brett, 1982); PNFI; PCFI; and PGFI parsimonious goodness-of-fit index (PGFI). All parsimony based fits are much lower than other norm fit measures and value <math>&gt; .60</math> are acceptable and satisfying (Blunch, 2008)</p> <p>□ Fit measures based on the non-central chi-square distribution include: 'Root Mean Squared Error of Approximation (RMSEA) (acceptable <math>&lt; .10</math>; good fit <math>&lt; .05</math>); and the P-values (PCLOSE) for the test of null hypothesis that is RMSEA is <math>&lt; .05</math>.</p> <p>In additional, there are divergent views on acceptable minimum criteria for model fit indices, several studies have different threshold for model best fits. Hence, the need for standardised metrics for reporting model fit including associated thresholds. Current study therefore formulated a fit threshold table based on best practice across previous studies.</p>
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## Appendix9: Initial Operational Sustainability Performance based on the OST

OPERATIONAL SUSTAINABILITY TOOL KIT- Physical Survey Sheet1												
OS Measurement Tool for Case Buildings: Likert's Scale of -2 to +2												
SN	Primary Index	Prim. Indicators: Indices	B101	B102	B103	B104	B105	B206	B207	B208	B209	B210
A	Climate											
1		Mitigation Policy	2	0	0	0	0	2	2	2	2	2
2		Adaption Measures	2	2	0	0	0	2	2	2	2	2
3		Comfort	2	2	1	2	0	1	2	2	2	1
B	Mgt- Policy											
4		CIEs	2	2	2	2	2	2	2	2	2	2
5		SSP	2	1	2	2	2	2	2	2	2	2
6		SFM	1	1	0	1	1	2	2	2	2	2
7		SEM	1	0	0	0	0	2	2	2	2	2
8		BAM	1	1	0	0	0	2	2	2	2	2
9		Edu. /Train. on EE	2	0	0	1	2	2	2	2	2	2
C	Operational											
10		Assmnt. / Benchmark	0	0	0	0	0	2	2	2	2	2
11		Energy Modelling	0	0	0	0	0	2	2	2	2	2
12		Reg. Energy Audit	1	2	1	2	1	2	2	2	2	2
13		Eff. Lighting/ Equip.	2	2	2	2	2	2	2	2	2	2
14		HVAC matching	2	1	0	1	0	2	2	2	2	2
15		BMS, BEMs Tech.	0	0	0	0	0	2	2	2	2	2
16		LZC solutions	0	0	0	0	0	0	0	0	0	0
17		Envelop Insulation	na	na	na	na	na	0	2	2	2	2
18		HVAC Efficiency	1	0	0	0	0	2	2	2	2	2
20		BCT	1	0	0	0	0	2	2	2	2	2
21		Main. / Retrofit	2	2	1	0	0	2	2	2	2	2
D	Reg. Policy											
22		Reg. Framework	0	0	0	0	0	2	2	2	2	2
23		Codes/ Standards	0	0	0	0	0	2	2	2	2	2
24		Energy Certification	0	0	0	0	0	2	2	2	2	2
E	Bus.Practice											
25		Poor Supply Chain	-2	-2	-2	-2	-2	2	2	2	2	2
26		Corruption	-2	2	-2	-2	-2	2	2	2	2	2
27		CSR	1	2	1	1	1	2	2	2	2	2
OST- SHEET1 SUB-TOTAL			21	18	6	10	7	47	50	50	50	49
SUB-TOTAL TO SUMMARY SHEET2			21	18	6	10	7	47	50	50	50	49
OPERATIONAL SUSTAINABILITY TOOL KIT- Physical Survey Sheet2												
OS Measurement Tool for Case Buildings: Likert's Scale of -2 to +2												
SN	Primary Indexes	Prim. Indicators-Indices	B101	B102	B103	B104	B105	B206	B207	B208	B209	B210
F	Culture											
28		Environ. Norms	1	0	2	2	2	2	2	2	2	2
29		Attitude	1	1	1	1	1	1	1	1	1	1
30		Habit	2	1	2	2	2	1	1	1	1	1
31		Intention	2	1	2	2	2	0	0	0	0	0
32		Behaviour	2	2	2	2	2	1	1	1	1	1
33		Info. Awareness	2	1	2	2	2	1	1	1	1	1
34		BCT	0	0	0	0	0	2	2	2	2	2
G	LZC Options											
35		Solar PV	0	0	0	0	0	0	0	0	0	0
36		MWT	0	0	0	0	0	0	0	0	0	0
37		CHP	na	na	na	na	na	0	0	0	0	0
38		Solar Thermal	0	0	0	0	0	0	0	0	0	0
39		LEDs	0	0	0	0	0	2	2	2	2	2
40		Inverter	0	0	1	0	na	na	na	na	na	na
41		GSHP	0	0	0	0	0	0	1	2	3	4
H	Barrier/Driver											
	Barriers											
42		Lack: Policy Frmwk	-2	-2	-2	-2	-2	2	2	2	2	2
43		Lack: Code/Standard	-2	-2	-2	-2	-2	2	2	2	2	2
44		Lack of Skills	-2	-2	-2	-2	-2	2	2	2	2	2
45		Political Unrest	-2	-2	-2	-2	-2	2	2	2	2	2
46		Electricity Supply	-2	-2	-2	-2	-2	2	2	2	2	2
47		Ineff. Behav.& style	0	0	0	0	0	0	0	0	0	0
48		Incomp. Inform	0	0	0	0	0	2	2	2	2	2
49	Strat. Drivers											
50		Asset Value	0	0	0	0	0	2	2	2	2	2
51		Market Force	0	0	0	0	0	2	2	2	2	2
52		SSP/SFM	0	0	0	0	0	0	0	0	0	0
53		SEM	1	1	1	1	1	2	2	2	2	2
54		PMs/KPIs	0	0	0	0	0	2	2	2	2	2
55		BEMTechs	1	1	0	0	0	2	2	2	2	2
56		TEBP	0	0	0	0	0	2	2	2	2	2
57		RETOS	0	0	1	0	0	2	2	2	2	2
58		BCT	0	0	0	0	0	2	2	2	2	2
I	PMs/KPIs											
59		BEU	na	na	na	na	na	na	na	na	na	na
60		BEUI	na	na	na	na	na	na	na	na	na	na
61		BCo2 Emission	na	na	na	na	na	na	na	na	na	na
62		BCo2 Intensity	na	na	na	na	na	na	na	na	na	na
63		BEC- Energy Cost	na	na	na	na	na	na	na	na	na	na
64		BECl- intensity	na	na	na	na	na	na	na	na	na	na
OST- SHEET2 SUB-TOTAL			2	-2	4	2	2	38	39	40	41	42
BF: OST- SHEET1 SUB-TOTAL			21	18	6	10	7	47	50	50	50	49
OST- SUMMARY SCORES			23	16	10	12	9	85	89	90	91	91
OST- % SCORE: OVERALL WEIGHTING			21.3	14.8	9.3	11.1	8.3	77.3	80.9	81.8	82.7	82.7

## Appendix 10: Location of Nigeria Case buildings



Sourced: Google map. <<http://www.Google.co.uk/maps/>> (Accessed 09/05/2016)



## Appendix11: Case Building ID101



Arup's head office: External View



Arup's head office: 5<sup>th</sup> Floor internal View

This is a privately owned seven-story office building, built in 1997 and refurbished in 2007 (Appendix11). It is a concrete framed-structure with deep raft foundations. Further it is made up of light-weight hollow block walls without insulation; and reinforced concrete floors built with light-weight hollow clay pots connected with reinforced ribbed beams. The internal floor

and external walls are finished with ceramic tiles. Also, its windows compose of aluminium single pane glazing, security bars, internal blinds and externally mounted aluminium metal grills for shading.

The building has a gross internal floor area (GIA) of 1306m<sup>2</sup> with a prototype office space design (open plan) from the 2<sup>nd</sup> floor to the 7<sup>th</sup> floor. The 1<sup>st</sup> floor (ground), has a built-in security office, stairwell and lift well entrances, plant rooms, parking lots and general toilet. The front approach is fitted with a coloured glazing curtain wall façade, which is the entrance to the stair and lift wells. It also, has an atrium with a fixed skylight for natural day-light gain.

The building is fitted with two passenger lifts, serviced with two generators (325kva and 60kva). The air conditioning system is the split unit, fluorescence lighting fittings and diffusers, while each floor has central printing station, and ICT control room. The building has 85 permanent staff; with occupancy ratio of 15.4m<sup>2</sup> per person; and 141,444 operational hours of 8am-5pm for week days.

## Appendix12: Case Building ID102



COG church and Zonal office: External View



COG church and Zonal office: Internal View- Ground Floor

This is a single-story building constructed in 1995, and refurbished in 2013 with GIA of 556m<sup>2</sup> (Appendix12). The building is constructed with normal pad and strip foundations; reinforced concrete floors; and hollow sandcrete block walls (internal and external) without insulation. It has a combination of open and closed plan ground floor space used as a worship centre, and the upper floor is partitioned into offices.

Its windows are made up of both single casement projection and sliding pane glazing types, fitted with burglar bars and internal blinds. The building is serviced with 60kVA and 5kVA generators (as power back-up), CCTV and sound room for programme and audio transmission. This building has seven permanent church staff on daily basis asides from worshippers, thus it has occupancy ratio of 79.4m<sup>2</sup> person. Also, it has 74,048 occupancy hour (church staff and worshippers' time); equipped with standalone and wall-mounted air conditioning units; and with fluorescence lighting fitted with diffusers.



### Appendix13: Case Building ID103



Miviti Comm. Ltd and Silvianazer Nig. Ltd. Offices



Miviti Comm. Ltd and Silvianazer Nig. Ltd. Offices

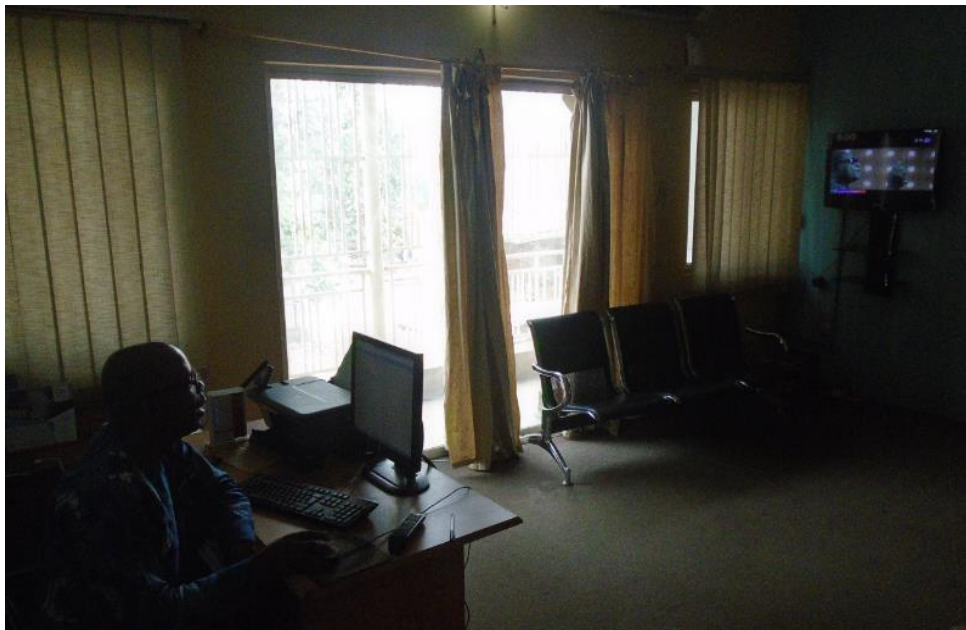
The facilities are 2nrs single-story separate buildings of 4nrs three-bedroom flat each, built in 1995 with GIA of 1220m<sup>2</sup> (Appendix13). They are domestic dwellings that have been converted into a mix of domestic dwelling and office usage, which is a common trend in low density areas of Lagos. It is also, constructed of pad and strip foundations; reinforced concrete floor; and sandcrete hollow block walls (internal and external) without insulations.

Its windows are made of single pane aluminium sliding construction, fitted with burglar bars; and each flat is being serviced with a power back-up generator. The air conditioners in each flat vary from window units to wall mounted split units. Furthermore, the building has 37,856 annual operational hours (staff and residents); and with 52 staff (including residents) overall, making 26nrs per block. Therefore, each block has occupancy ratio of 48.8m<sup>2</sup> per person, and the building is maintained by residents.

#### Appendix14: Case Building ID104



Centu-serve office Building: External View



Centu-serve office Reception: External View

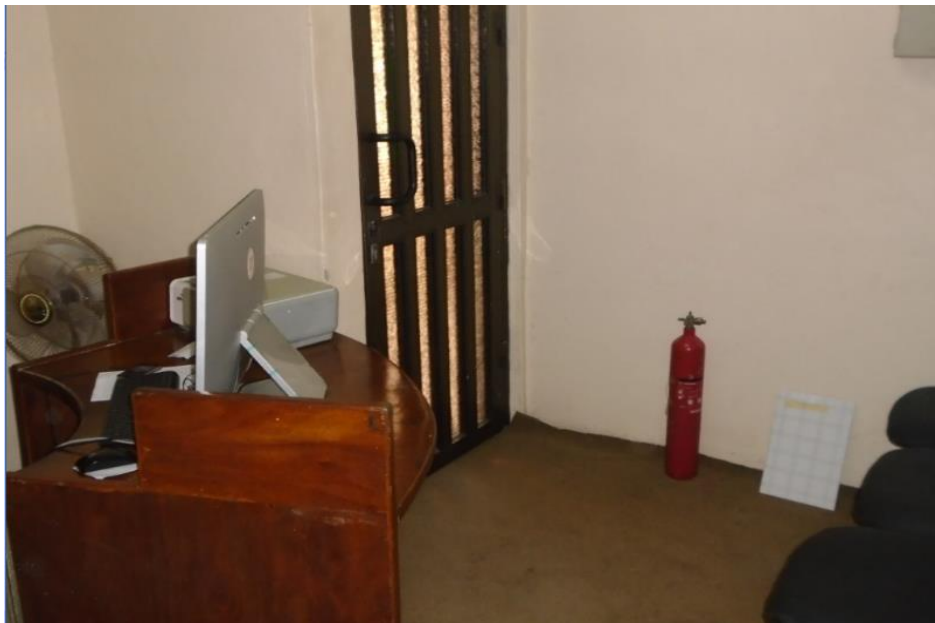
This a block of four-flat and open plan ground floor (as banking hall), three-story office building (Appendix17). It was built in 1993 with GIA of 864m<sup>2</sup> upon pad foundations with interconnecting ground beams. It is a reinforced concrete framed-structure with reinforced floor slabs. Its internal and external walls are built of sandcrete hollow block wall without insulations.

The windows are made of aluminium sliding single pane glazing with security burglar bars and blinds as shading. Each office per flat owned a power back-up generator and the entire facility is owner-self manage. Whilst, it's installed air-conditioners varies between window and wall-mounted split units. The lighting fittings are normal fluorescence without diffuser, and each office is equipped with computers and printers work stations. Also, the operational schedule of building is week days: 8.0am- 6.0pm and Saturday 10am- 2.0pm thus, it has occupancy ratio of 23.7m<sup>2</sup> per person.

## Appendix15: Case Building ID105



Cornices office building: External View



Cornices office Reception: 3<sup>rd</sup> Floor Internal View

This building is a 1,398m<sup>2</sup> (GIA) reinforced concrete framed-structure office complex built in 1987 (Appendix15). It is built upon pad foundations interconnected with deep ground beams; reinforced concrete floor slabs; light-weight hollow block walls without insulation; and single panel sliding and projected aluminium windows. The windows are fitted with security burglars and internal blinds as shade.

The building has twenty office units occupied by different organisations. It is being managed by the owner and a lift service company. The building is serviced by one lift which was out of use due to breakdown as at the time of study. Also, each organisation has a back-up generator; at least two wall / split units' air conditioners; and computers/ printer workstations.

In all, a total of twenty generators and at least forty AC are installed within inside this facility. The lighting are similar proto-type appliances like other case buildings. Whilst, it's operational schedule are 8.0am- 6.0pm for week days; and 10am- 2.0pm for Saturday. Hence, it has occupancy ratio of 16.6m<sup>2</sup> per person.



## Appendix 16: Location of UK Case buildings



Sourced: Google map. <<http://www.Google.co.uk/maps/>> (Accessed 09/05/2016)



## Appendix17: Case Building ID206



Marconi Building: External View



Marconi Building: Staff Room Internal View

The Marconi building is three-storey steel framed structure of about 5351m<sup>2</sup> GIA built on 225nrs structural steel piled foundation (Appendix17). The building is made up of lightweight walls comprising of block work, curtain walls (Kawneer1202 Series) and vertical cladding (1352m<sup>2</sup>) of 0.7mm pre-weathered zinc coils. It has two stair wells (on the northern and southern wings), and two lift wells fitted with mechanical lifts.

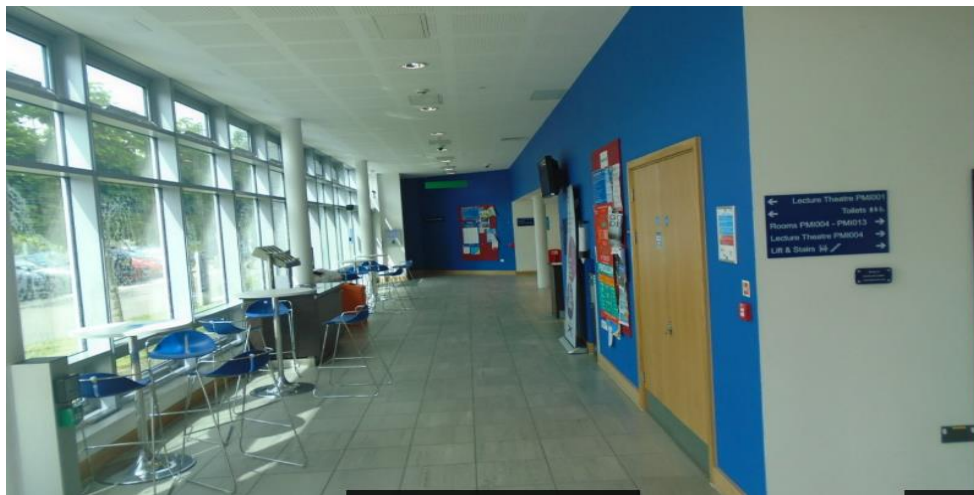
Marconi façade is made up of Metsec external wall and a structural steel framework canopy. It also has composite Veltec 200 series window system with 24mm double glazed unit; and 500-600 series aluminium door sets and frames with polyamide thermal break. It is fitted with Levolux 910XL Matrix sun breaker louvre system, and lightex blackout blinds. The building comprises of lecture theatre, I-centre, offices and convenient rooms.

It is fitted with under mechanical ventilation with air supply diffusion grills as central vent running through the length of each floor's soffit. Other installations are: access door controller, access lock, CCTV, fire detection and smoke fire dampers. The lecture theatre is fitted with under-tier floor ventilation grilles. Marconi have lighting movement sensors, override light switches, BMS meters and other energy saving devices.

## Appendix18: Case Building ID207



PMI Building: External View



PMI Building: Entrance Lobby Internal View

The Post Medical Institute (PMI) building is a three-storey building in steel framed structure built on concrete piled foundations (Appendix18). It is made of in situ concrete floor with 2639m<sup>2</sup> GIA. The wall is made of combination of blockwork, Remit rain screen, curtain walling and window fitted with 16mm argon glass. The roof is in three levels; at first floor level over the entrance, second floor level over the larger lecture theatre, and main roof over second floor. The roof is made of Bauderflex roof system incorporating 110mm Bauder pir insulation on new metal deck.

PMI is made of two stairwells, 2hrs lecture theatres (200-seat and 400-seat capacities), a bio-mechanical laboratory, and hub rooms. It is installed with automatic powered sliding door with emergency breakout facility and rotating entrance door. Its services installation includes: BMS system, chiller and HP, emergency lighting system, fire smoke damper, fire detection etc.

## Appendix19: Case Building ID208



Mildmay Building: External View



Mildmay Building: Basket Ball/ Examination Hall Internal View

Mildmay (sports hall) is a structural steel framed building, built on mass concrete pad and strip footing foundations (Appendix19). The floor is made of in-situ concrete of about 975m<sup>2</sup> GIA, and built with non-load bearing walls (blockwork). The principal elements of the building include indoor sport hall, offices including fitness, changing and shower rooms.

The building is fitted with aluminium framed entrance canopy and door with glazed surrounds and panels over. The window is aluminium framed double glazed fixed with top hung opening. The HVAC installations include: split air conditioners, heating system, fire alarm, water heater and sanitary wares.



## Appendix20: Case Building ID209



Tindal Building: External View



Tindal Building: Ground Floor Stairwell Internal View

The Tindal building is a four-storey student centre built with reinforced concrete framed structure on piled foundations (Appendix20). The wall is made of combination of blockwork, timber rain screen cladding and glazing. The façade is fitted with steel frame canopy covered with single layer polymeric roofing sheet. It has two precast concrete stairwells, a steel stair case and one passenger lift.

The main elements consist of student union bar, restaurants, offices and meeting rooms. The building installed HVAC includes: air conditioners, heating system, ventilation system, controls, boilers and comfort cooling system etc.

## Appendix21: Case Building ID210



Ashcroft Building: External View



Ashcroft Building: Entrance Lobby Internal View

Lord Michael Ashcroft building is a four-storey UB steel framed structures of 3723m<sup>2</sup> GIA, built on piled foundations (Appendix21). It also comprises of steel framed auditorium structure with gravity roof fixed with symphonic drainage. The building wall is made of curtain wall, bio-climate wall, glazed cladding, glass louvres and venetian blinds on windows.

Ashcroft building steel frames include also foyer with curtain wall, aluminium revolving and hinged doors. The building main elements also include lecture room, convenient, offices, etc. Its services include BMS system, fire alarm/ detection, fire dampers, etc.

## Appendix22: Quest-Surv1

### *2ND POST OCCUPANCY EVALUATION SURVEY ON DRIVERS FOR REDUCING ENERGY CONSUMPTION OF EXISTING BUILDING STOCKS BY BLESSING MAFIMISEBI*

#### 1. QUESTIONNAIRE FOR END-USERS AND OWNERS

##### GENERAL

Welcome to the second Post Occupancy Evaluation (POE) survey of existing office buildings Nigeria and United Kingdom, regarding five Buildings in Chelmsford, United Kingdom and five Buildings in Lagos, Nigeria.

The aim of this case study survey is to serve as confirmation and an explanatory study for the gathering of quantitative data on the energy efficiency performances of these buildings.

Your participation is voluntary, and you are not under any form of compulsion to respond to all or any of these questions and the entire survey.

All information given is for academic purpose and will be treated with strict confidentiality. Thank you for your participation.

#### 2. SECTION 1. GENERAL BACKGROUND

Please indicate the most applicable to you in the following questions 1-7

##### 2. SECTION 1. GENERAL BACKGROUND

###### 1. Please indicate your country of residence

- ☐ Nigeria
- ☐ United Kingdom

###### 2. Nigeria if applicable: please indicate your work location

- ☐ Arup Building
- ☐ Centu- Serve Building
- ☐ RCCG COG Zonal head-office Building
- ☐ Austin Ejike Buildings
- ☐ Cornices Consult Building

###### 3. United Kingdom if applicable: please indicate your work location

- ☐ Marconi Building
- ☐ PMI Building
- ☐ Michael Ashcroft Building
- ☐ Tindal Building
- ☐ Mildmay Building

###### 4. Which of the following categories best describe your user status of this building

- ☐ Staff
- ☐ Student
- ☐ Employee of business organisation
- ☐ Employer / Owner

###### 5. How long have you being working in this building?

- ☐ < 5years



- 6-10years
- 11-15years
- 16-20years
- 21-25years
- Other (please specify)

6. On the average, how many days do you spend inside this building in a normal working week?

- 1day
- 2days
- 3days
- 4days
- 5days
- Other (please specify)

7. on the average, how many hour(s) per day do you spend in this building in a normal working day?

- 1-2hrs
- 3-4hrs
- 4-5hrs
- 6-8hrs
- Other (please specify)

#### 4. SECTION 2. BUILDING CONTROL SYSTEMS AND THEIR AWARENESS

8. Please rate the usefulness of these equipment to you in this building, using a scale of 1 (very irrelevant) to 5 (very relevant):

- |  |               |
|--|---------------|
| Very irrelevant  | Very relevant |
| <ul style="list-style-type: none"> <li>● Building Energy Management System (BEMS) or Building Automaton</li> <li>● System (BAS)</li> <li>● Data Acquisition System (DAS)</li> <li>● Installed Access Control Lock</li> <li>● Installed Lighting Controls (Sensors)</li> <li>● Installed Temperature &amp; Humidity Controls</li> </ul> |               |

9. Technologies (BEMS, Censors, DAS, etc.) help drives building energy efficiency performance. Please indicate your opinion based on the ranking scale of 1 (being strongly disagreed) to 5 (being strongly agreed):

- Strongly disagreed
- Disagreed
- Neutral
- Agreed
- Strongly agreed

#### SECTION 3: BUILDING ENERGY PERFORMANCE AND COMFORT

10. On a scale of 1 (being very uncomfortable) - 5 (being very comfortable), please describe this building under the following metrics:

Very uncomfortable; Uncomfortable; Neutral; Comfortable; Very comfortable

- Indoor air temperature  
During the summer (dry  
Season): Overall
- Indoor air temperature  
During the winter (rainy  
Season): Overall

11. Please rate this building based on the metrics below using a scale of 1 (being very unsatisfactory) - 5 (being very satisfactory)

Very unsatisfactory; Unsatisfactory; Neutral; Satisfactory; Very satisfactory

- Natural Day Light
- Comfort: Overall
- Electrical Lighting: Overall
- Health (Perceived)
- Noise: Overall
- Ventilation (Natural)

12. Please rate the following correlations for this building base on your perceived judgement, using a scale of 1 (being very weak) to 5 (being very strong)

Very weak; Weak; Neutral; Strong; Very strong

- This building's energy use and its comfort
- This building energy use and facilities  
Management cost
- This building energy use and its carbon emissions
- This building energy use and management  
Sustainability policy
- This building energy use and occupant behaviour

## 6. BUILDING ENERGY PERFORMANCE AND COMFORT CONT'D

13. Please indicate the level of your control on these aspects of the building, using a rating of 1 (being having no control) to 5 (being having full control)

No Control; Neutral; Having Control

- Heating
- Cooling
- Day Light
- Noise level
- Ventilation
- Lighting
- Shading (Blinds)

14. Kindly rate your energy efficiency habit on the use of this building, using a scale of 1 (being strongly disagree) to 5 (being strongly agree)

Strongly Disagree; Disagree; neither Disagree nor Agree; Agreed; Strongly Agree

- I switch off often: Generally
- I switch off sometimes: Generally
- I don't switch off: Generally

15. Please kindly indicate your energy behaviour intention in the following, using a scale of 1 (being strongly disagreed) to 5 (being strongly agreed)

Strongly disagreed; Disagreed; Neutral; Agreed; strongly agreed

- I switch off to conserve energy
- I switch off to reduce this  
Building energy cost
- I switch off to reduce Carbon  
Emissions from this building

6. SECTION 4. ENERGY EFFICIENCY PERFORMANCE AND FACILITIES  
MANAGEMENT/ MAINTENANCE DEPARTMENT

16. Facilities management (FM) is a useful tool for reducing building energy use. Please indicate your agreement or disagreement by using 1 (being strongly disagreed) to 5 (being strongly agreed)

- Strong disagreed
- Disagreed
- Neutral
- Agreed
- Strongly agreed

17. Planned & Routine maintenance and Energy retrofit are effective drivers for building energy performance. Please rank your agreement or disagreement by using a scale of 1 (strongly disagreed) to (strongly agree)

- Strongly disagreed
- Disagreed
- Neutral
- Agreed
- Strongly Agreed

18. Regular energy assessment (audit) & bench-marking will help reduce the energy use and energy cost of this building. Please rank your opinion based on the following:

- Strongly Disagreed
- Disagreed
- Neutral
- Agreed
- Strongly Agreed

7. SECTION 5. CLIMATE CHANGE, BUILDING SUSTAINABILITY, ENERGY  
EFFICIENCY AND CARBON EMISSION

19. On these Global Issues, please rank your level of awareness in relation to Building energy use, using a scale of 1 (being not fully aware) to 5 (being fully aware)

Not Fully Aware; Not Aware; neither Unaware or Aware; Aware; Fully Aware

- Climate Change
- Global Warming

- Sustainable Development
- Carbon Dioxide Emission
- Energy Efficiency
- Carbon Footprint
- Building Energy Efficiency Performance

20. Emission from energy use in all buildings (including this) is now a global concern, could you please indicate your willingness by ranking the level of your concerns using 1 (being not fully concerned) to 5 (being fully concerned)?

Not Fully Concerned; Not Concerned; Neutral Concerned; Fully Concerned

- Willingness to change to More energy efficient Habit
- Willingness to Reduce Carbon footprint of this building
- Willingness to Reduce this Building's energy Consumption
- Willingness to reduce Global warming

21. Global sustainability agenda and corporate sustainability policy are effective drivers for reducing building energy use and its carbon emission. Please indicate your opinion with the following:

- Strongly disagreed
- Disagreed
- Neutral
- Agreed
- Strongly agreed

22. Occupant's awareness on building energy efficiency and environmental issues (norms) help reduce energy use and carbon emission from buildings. Please indicate your opinion as follows:

- Strongly disagreed
- Disagreed
- Neutral
- Agreed
- Strongly agreed

## 9. SECTION 6. CONCLUSION: BARRIERS & DRIVERS- SUSTAINABLE MANAGEMENT OF BUILDING TO REDUCE ITS USE

23. The following are perceived barriers to building energy use efficiency. Please rank your agreement or disagreement base on a scale of 1 (being strongly disagreed) to 5 (being very strongly agreed):

Strongly disagreed; Disagreed; Neutral; Agreed; strongly agreed

- Lack of regulatory policy & institutional framework
- Lack of building energy Codes and standards

- Incomplete/ imperfect information  
On energy efficiency
- Behaviour & Lifestyle
- Poor energy supply chain
- Sharp practices
- Lack of technical skill

24. The following is perceived drivers to building energy use efficiency. Please rank your agreement or disagreement base on a scale of 1 (being strongly disagreed) to 5 (being very strongly agreed):

Strongly disagreed; Disagreed; Neutral; Agreed; strongly agreed

- Embedded Sustainability Policy &  
Strategic Facilities Management
- Transparent & ethical business practices
- Behavioural change tool
- Energy performance Metrics &  
Indicators for Assessment & Benchmark
- Renewable energy technology option
- Strategic Energy management
- Building Energy Management  
Technologies

## Appendix23: Quest-Surv2

### *METRICS AND INDICATORS FOR ASSESSING AND BENCHMARKING BUILDING ENERGY PERFORMANCE BY BLESSING MAFIMISEBI*

#### GENERAL: QUESTIONNAIRE FOR OPERATORS / FACILITY MANAGERS

Welcome to this survey on the choice of appropriate performance metrics and key indicators for building energy assessment and benchmark as tool for operators and facility managers.

The aim of this survey is to serve as an exploratory study for the gathering of quantitative and qualitative data on the relevance of the roles of facility managers, and the appropriate metrics / indicators that can be used for building energy efficiency performance assessment and benchmark.

Your participation is voluntary and you are not under any form of compulsion to respond to all or any of these questions and the entire survey.

All information given is for academic purpose and will be treated with strict confidentiality. Thank you for your participation.

#### SECTION 1. DEMOGRAPHIC

1. What is your gender?

- ☐ Female
- ☐ Male

2. Please indicate your current location

- ☐ United Kingdom
- ☐ Nigeria
- ☐ Other (please specify)

3. Please indicate as appropriate, your membership status of any of these professional bodies if applicable (UK).

Student; Graduate Member; Associate Member; Corporate member; Fellow; Not Applicable

- British Institute of Facilities Managers (BIFM)
- Royal Institution of Chartered Surveyors (RICS)
- Chartered Institute of Building Services Engineers (CIBSE)
- Institute of Civil Engineers (ICE)
- Chartered Institute of building (CIOB)
- Other (please specify)

4. Please indicate as appropriate, your membership status of any of these professional bodies if applicable (Nigeria).

Student; Graduate Member; Associate Member; Corporate member; Fellow; Not Applicable

- Nigeria Institute of Facilities Managers (NIFM)
- Nigeria Institute of Estate Surveyors & Valuers (NIESV)
- Nigeria Institute of Builders (NIOB)
- Nigeria Society of Engineers (NSE)
- Nigeria Institute of Quantity Surveyors (NIQS)
- Nigeria Institute of Architects (NIA)
- Other (please specify)

5. What is the highest level of education you have attained?

- GCE's / O Levels
- A Levels
- NVQ
- HND/BSc/BEng or Other First Degree
- Masters
- Doctorate
- Other (please specify)

6. Please indicate the type of Facilities Management (FM)/ maintenance organisation you work in.

- End-user (In-house Facilities management (FM) / maintenance Department)
- FM Company (outsourced full FM service provider)
- FM product suppliers
- Consultant (independent)
- Other (please specify)

7. What sector can you classify your organisation into?

- Government / Public Corporation
- Oil & Gas
- Manufacturing
- Construction & Allied Services
- Transport / Logistics
- Education
- Healthcare
- Banking / Finance
- Other (please specify)

8. The following could best describe your level of involvement as a facility manager, please indicate your agreement or disagreement using a scale of 1 (strongly disagree) to 5 (strongly agree)

Strongly Disagreed; Disagree; Neutral; Agree; Strongly Agree

- Managing the physical fabric of existing/ new Buildings
- Managing the equipment and furniture Within facilities
- Facility's Energy Management
- Facility's Waste management
- Facility's Routine & Emergency Repairs, Planned Maintenance and Refurbishment
- Monitor and measure all sustainability policies



Metrics to achieve targeted sustainable goals

## SECTION 2. SUSTAINABILITY AGENDA AND BUILDING ENERGY PERFORMANCE

9. Please, could you indicate the extent of your agreement to the following with a scale of 1 (being strongly disagree) to (being strongly agree)?

Strongly Disagreed; Disagreed Neutral; Agreed; Strongly Agree

- Sustainability agenda and policies drives Energy performance of facilities
- My organisation has written and Implements sustainable policy
- My organisation has no sustainable policy
- My organisation often takes steps in Reducing her energy consumption bills
- Building energy consumption is the outstanding Significant cost item during its operational lifecycle cost.

10. Could you please, describe the content of your organisation's sustainable policy by ranking the following, using a scale of 1 (Certainly Unsure) to 7 (Certainly Sure)

Certainly Unsure - Certainly Sure

- Building Disposal
- Energy Management
- Waste and Water Management
- Ethical Purchasing & Carbon Foot printing
- Staff Training & Productivity
- Community Engagement/ Involvement
- Health, Safety & Environment
- Sustainable Products, Services, & Travels
- Flexible Working Hour

11. some of these could be taken as perceived drivers for the implementation of sustainable energy consumption in your organisation, please indicate your agreement or disagreement with a scale of 1 (strongly disagree) to 5 (strongly agree):

Strongly Disagree; Disagree; Neutral; Agree; Strongly Agree

- Corporate Image
- Legislation
- Organisation Ethos
- Senior Management/ Director's Leadership
- Building Energy Lifecycle Reduction
- Building Carbon Footprint Rating

## SECTION 3. FM's RESPONSIBILITIES AS DRIVERS FOR ENERGY EFFICIENCY AND ZERO EMISSION

12. Please indicate the degree to which you believe FMs can influence building energy efficiency, using ranking of 1 (being strongly disagree) to 5 (strongly agree).

Strongly Disagree; Disagree; Neutral; Agree; Strongly Agree

- Planning and ensuring efficiency  
Supply of resources
- Influencing the behaviour of individuals  
Working within the Building facility they manage
- Develop and implement programmes to  
Reduce energy consumption of facility
- Adopting energy efficiency measures  
Like switching to efficient lighting equipment
- Review and monitoring the total facility Energy used
- Matching heating & cooling & Ventilation  
Equipment to facility loads to reduce energy consumption
- Develop and implement energy retrofit programme
- Identify energy performance indicators for monitoring progress
- Monitoring and evaluating carbon footprint, including  
Responsibility for target, measurement and reporting

13. Please indicate what you consider to be an effective barrier to building energy efficiency by rating these statements on a scale of 1 (being strongly disagree) to 5 (being Strongly Agree).

Strongly Disagreed; Disagreed; Neutral; Agree; Disagreed

- Inefficient Occupant's behaviour
- Faulty building envelope due to age and disrepair
- Insufficient thermal insulation of Building envelope
- Lack of funding to install control sensors  
& sub metering equipment
- Lack of awareness of energy efficiency measures
- High cost of implementing energy efficiency programmes
- Lack of management commitment
- Lack of appropriate frameworks for reducing energy consumption

14. Some of the perceived barriers to FM's practices are listed below, please rate their impact on facility energy efficiency performance. (1 being very weak barrier to 5 being very strong barrier)

Very weak barrier; Weak barrier; Neither Weak nor Strong; Strong Very strong

- Lack of training
- Lack of appropriate tools
- Lack of awareness of the responsibilities of FM
- Lack of appropriate strategic energy efficiency policy by organisations
- Lack of knowledge of energy efficiency measures by FM practitioners
- Lack of senior management commitment

#### SECTION 4. FACILITY ENERGY USE, MONITORING & CONTROL

15. I have experience in managing buildings with Building Energy Management System (BEMS) and Data Acquisition System (DAS). Please confirm this by indicating below

- ☐ Yes
- ☐ No

16. Please indicate the numbers of buildings with BEMS & DAS that you have managed in the past.

- ☐ 1-5
- ☐ 6-10
- ☐ 11-15
- ☐ 16-Above

17. In your assessment, how do the occupants' behaviour tallies with real time energy efficiency measures (installation of BEMS & DAS). Please indicate your agreement or disagreement using a scale of 1 (Strongly disagree) to 5 (Strongly agree)

Strongly Disagreed; Disagreed; Neutral; Agreed; Strongly Agree

- Occupant's behaviour complements BEMS/DAS installation of facilities
- Occupant's behaviour does not complement BEMS/DAS installation of facilities
- Most occupants are unaware of BEMS/DAS installations & functions on facilities
- Most occupants are aware of BEMS/DAS Installations & functions on facilities
- Most occupants feel good using BEMS/DAS Installations on facilities

18. Based on your professional judgement, please rank these as factors influencing building energy use, using a scale of 1(very ineffective) to 7(very effective)

Ineffective -Very Effective

- Climate
- Building Envelope
- Building Electrical/ Mechanical Equipment
- Operation & Maintenance
- Occupant's Behaviour
- Indoor Environment Condition
- Building Size

19. When managing facilities, how do you prioritise your decisions in terms of the following?

- ☐ Facility performance in terms of intended use
- ☐ Facility management in terms of sustainability goals
- ☐ Facility operational lifecycle cost
- ☐ Facility lifecycle energy cost and carbon footprint

- Return on investment (capital replacement cost)

20. Based on your experience, please rate these as top priorities for reducing building energy Consumption.

- Occupant Behaviour
- Energy Monitoring & Control (installation of BEMS/DAS)
- Efficient Thermal Envelope
- Efficient Electrical/Mechanical installation
- Consistent, Maintenance & Repairs
- On-site Renewable Installation Option

## SECTION 5. TECHNICAL, OPERATIONAL, & MANAGERIAL SOLUTIONS FOR ENERGY EFFICIENCY PERFORMANCE

21. Please rate based on its effectiveness for purpose, these perceived technical solutions used for reducing facility's energy consumption using a scale of 1(very ineffective) to 7(very effective).

Ineffective - Very Effective

- Usage of energy consumption framework by management
- Regular energy audit for facility
- Regular Assessment and Benchmarking (monitor, measure, review, & rate)
- Installation of BEMS & DAS
- Installation of PV solar panel
- Matching heating, cooling & ventilation equipment to Facility loads
- Switching to more efficient lighting & Equipment

22. Please rate these managerial and operational solutions for energy efficiency, based on your perception of their effectiveness using sale of 1(very ineffective) to 7(very effective)

Ineffective - Very effective

- Incorporation of sustainable policy in organisation's policies
- Establishment of strategic energy performance/ efficiency policies
- Establishment of energy performance goals
- Formulation & implementation of energy performance policies
- Education & Training of Occupants on Efficient & use of BEMS / DAS
- Frequent physical walk through & inspection process
- Frequent planned, routine and emergency
- Maintenance, repairs and refurbishment

## SECTION 6. PERFORMANCE METRICS, INDICATORS, AND BENCHMARKS.

23. Some of the perceived energy performance metrics are listed below, please rate the strength of each as a metric with a scaling of 1 (very weak) to 7 (very strong)

Very Weak - Very Strong

- Building energy use intensity (kWh/m<sup>2</sup>/yr.)

- Carbon Dioxide emission (kgCO<sub>2</sub>/m<sup>2</sup>/yr.)
- Electric energy use (kWh/m<sup>2</sup>/yr.)
- Heating energy use (therms/m<sup>2</sup>/yr.)
- Cooling energy use (kWh/m<sup>2</sup>/yr.)
- Ventilation energy use (kWh/m<sup>2</sup>/yr.)
- Lighting energy use (kWh/m<sup>2</sup>/yr.)
- Net facility energy use (kWh/m<sup>2</sup>/yr.)
- Plug loads energy use (kWh/m<sup>2</sup>/yr.)
- People mover energy use (kWh/m<sup>2</sup>/yr.)
- Domestic hot water energy use (kWh/m<sup>2</sup>/yr.)

24. The following are some of the key performance indicators (KPIs) for monitoring energy performance of buildings, please rate each base on its strength as a KPI. Use a scale of 1 (Very weak) to 7 (Very strong).

Very Weak - Very Strong

- Energy used intensity indicator (kWh/m<sup>2</sup>/yr.)
- Operational Rating (kgCO<sub>2</sub>/kWh)
- Comfort metric (av. Comfort index- 0-100)
- Lighting Energy Consumption (kWh/m<sup>2</sup>/yr.)
- Energy Performance Indicator (total HVAC energy consumption)
- End-Use Energy Indicators
- Asset Rating Indicator
- Occupant Stability Indicator
- U-value Performance Indicator
- Air Permeability Indicator

25. What benchmark would you use in comparing the energy performance of your building?

Its own past

- ☐ Performance of its peers
- ☐ Rated EER
- ☐ Established Rule of Thumb
- ☐ Established Benchmark
- ☐ Other (please specify)

## SECTION 7. SURVEY COMPLETION

Thank you for your patient and cooperation in completing this questionnaire.

Please feel free to contact me through the email address below for the result of this survey.

<blessing.mafimisebi@student.anglia.ac.uk>

## Appendix24: Quest-Surv3

### *VALIDATION SURVEY ON STRATEGIES FOR REDUCING ENERGY CONSUMPTION OF EXISTING BUILDING STOCKS BY BLESSING MAFIMISEBI*

#### 1. QUESTIONNAIRE FOR FACILITIES' MANAGERS, USERS AND OWNERS GENERAL.

Welcome to the validation survey on energy use of existing office buildings in Nigeria and United Kingdom. The aim of this validation study is to serve as a confirmatory study of the quantitative data gathered on the energy efficiency performances of these buildings.

Your participation is voluntary, and you are not under any form of compulsion to respond to all or any of these questions and the entire survey.

All information given is for academic purpose and will be treated with strict confidentiality.

Thank you for your participation.

#### DEMOGRAPHY.

Please indicate most applies to you

#### 2. GENERAL BACKGROUND

##### 1. Please indicate your country of residence

- ☐ Nigeria
- ☐ United Kingdom

##### 2. Please indicate your corporate status below:

- ☐ Facilities / Property managers
- ☐ MD/ CEO/ Owners
- ☐ Staff
- ☐ Student

##### 3. Please, kindly indicate your academic qualification

- ☐ GCE Level
- ☐ First Degree /H.N. D
- ☐ Master Degree
- ☐ PhD
- ☐ Qualified professional Certification
- ☐ Other (please specify)

#### 3. OPERATIONAL, TECHNICAL, & MANAGEMENT AS PROPELLING FACTORS

4. Please rank the following operational solutions as propelling factors for reducing building energy use

Very weak; Weak; Neutral strong; Very strong

- Management's use of Energy consumption model
- Regular facility's energy audit
- Regular Assessment & Benchmarking

- Matching heating, Cooling & Ventilation equipment to Facility Loads
- Switching to more Efficient lighting & Equipment

5. Please rank the following technical solutions as propelling factors for reducing building energy use

Very weak; Weak; Neutral strong; Very strong

- Strategic Sustainability Policy
- Strategic energy Management
- Built asset management
- Corporate Image & Ethos
- Education & training on User's energy efficient Behaviour & use of Installed technology

#### 4. BUILDING ENERGY USE REDUCTION SOLUTIONS

6 Embedded sustainability policies combined with Strategic facilities management has been identified as propelling factors for reducing building energy use, please rank your opinion as follows:

- Strongly disagreed
- Disagreed
- Neutral
- Agreed
- strongly agreed

7. The following behavioural change tool variables have been identified as propelling factors for reducing energy consumption. Please rank base on perceived judgement, your agreement or disagreement as follows:

Strongly disagreed; Disagreed; Neutral; Agreed Strongly agreed

- Information dissemination  
On building energy efficiency
- Incentives & intervention programme
- Strategic change process
- Management involvement as advocate
- Post occupancy evaluation of self-report
- Energy assessment Monitoring & control of Occupant behaviour

8. Renewable energy solution was identified as propelling factor for building energy use efficiency, please rate the low-zero carbon option base on their effectiveness:

Very ineffective; Ineffective; Neutral; Effective; Very effective

- Solar PV panels
- Solar thermal
- Micro wind turbine
- Inverter lighting Technology- dry cell
- Ground source heat pump
- Combined heat & power
- Efficient lighting (LEDs)



9. Building energy Assessment & Benchmarking tool that incorporate building's portfolios (sustainability policy, strategic FM, technology & low-zero carbon option) based ranking will help inform better performance.

- Strongly disagreed
- Disagreed
- Neutral
- Agreed
- Strongly agreed

## 5. BUILDING ENERGY PERFORMANCE AND CONCEPTS

10. There is significant correlation following variables and building energy use reduction. Please your opinion as follows:

Yes; Neutral; No

- Strategic management of building
- Strategic FM
- Strategic Sustainability policy
- Inefficient occupant Behaviour
- Regular energy assessment
- Facilities manager's roles
- Standard energy performance metrics & indicators
- Installed BEMS, DAS /CENSORS
- Awareness & Complete Information

## 6. BARRIERS & DRIVERS: SUSTAINABLE MANAGEMENT OF BUILDING TO REDUCE ITS USE

11. The following is perceived barriers to building energy use efficiency. Please rank your agreement or disagreement base on a scale of 1 (being strongly disagreed) to 5 (being very strongly agreed):

Strongly disagreed; Disagreed; Neutral; Agreed; strongly agreed

- Lack of regulatory policy and institutional framework
- Lack of building energy Codes and standards
- Incomplete/ imperfect Information on energy Efficiency
- Behaviour & Lifestyle
- Poor energy supply chain
- Corruption- Sharp practices
- Lack of technical skill
- Oil & Gas politics and labour unrest
- Grid electricity generation Supply-demand deficit

12. Planned & Routine maintenance and Energy retrofit are effective drivers for building energy performance. Please rank your agreement or disagreement by using a scale of 1 (strongly disagreed) to (strongly agree):

- Strongly disagreed
- Disagreed
- Neutral
- Agreed

- Strongly Agreed

13. Regulatory Policy framework (institutional framework, building codes and standards, labelling are effective drivers for building energy performance. Please rank your agreement or disagreement by using a scale of 1 (strongly disagreed) to (strongly agree):

- Strongly disagreed
- Disagreed
- Neutral
- Agreed
- Strongly Agreed

## 7. BARRIERS & DRIVERS: SUSTAINABLE MANAGEMENT OF BUILDING TO REDUCE ITS USE CONTD

14. Facilities management (FM) is a useful tool for reducing building energy use. Please indicate your agreement or disagreement by using 1 (being strongly disagreed) to 5 (being strongly agree):

- Strong disagreed
- Disagreed
- Neutral
- Agreed
- Strong agreed

15. The following is perceived drivers to building energy use efficiency. Please rank your agreement or disagreement base on a scale of 1 (being strongly disagreed) to 5 (being very strongly agreed):

Strongly disagreed; Disagreed; Neutral; Agreed; strongly agreed

- Embedded Sustainability Policy & Strategic Facilities Management
- Transparent & ethical business Practices
- Behavioural change tool
- Energy performance Metrics & Indicators for Assessment & Benchmark
- Renewable energy technology option
- Strategic Energy management
- Building Energy Management Technologies

## 8. CONFIRMATION OF SELECTED PERFORMANCE METRICS & KEY INDICATORS

16. Based on the result from the first stage survey, the building energy performance metrics have been identified as strong and effective assessment metrics. Please rank each in order of preference.

- Building Energy Use (kWh/yr.)
- Carbon Emission (kgCo2e/yr.)
- Building Energy Cost (£, ₦/yr.)
- Heating Energy Use (kWh/yr.)
- Cooling Energy Use (kWh/yr.)
- Net Facilities Energy Use (kWh/yr.)

19. Based on the result of the first stage survey, the building energy performance indicators have been identified as strong and effective assessment metrics. Please rank each in order of preference.

- Building Energy Use Intensity (kWh/m<sup>2</sup>/yr.)
- Operational Rating (kgCo<sub>2</sub>e/m<sup>2</sup>/yr.)
- Building Energy Cost Intensity (£, ₦/m<sup>2</sup>/yr.)
- Building Energy Cost Intensity (kWh/m<sup>2</sup>/yr.)
- HVAC Energy Performance indicator (kWh/m<sup>2</sup>/yr.)
- Net Facilities Energy Use (kWh/yr.)
- End-Use Energy Indicator (kWh/m<sup>2</sup>/yr.)
- U-value Performance Indicator

20. Based on the result of the first stage survey, the building energy performance indicators have been identified as strong and effective benchmark methods. Please rank each in order of preference.

- Established Benchmark
- Its Own Past
- Performance of its Peers
- Rated EER

## 9. CONCLUSION: COMMERCIAL BUILDING ENERGY USE ISSUES

21. Please rank the importance of the following variables as issues affecting the commercial building's energy use, using a scale of 1 (very unimportant) to 5 (being very important).

Very unimportant; Unimportant; Neutral; Important; Very important

- Climate- building mitigation & adaptation and weather
- Strategic building Management-BAM
- Operational Framework: Technology, Skill, Metrics & indicators, strategic FM,
- Cultural context: Beliefs, norms, attitude, intention & Behaviour
- Barriers & driver's context: Sustainability, FM., Market forces, asset value
- Regulatory Policy context
- Business Practices context: Ethos, Corruption, supply chain
- Low-zero carbon option: Solar PV, Solar thermal, micro-wind turbine, Inverter lighting technology

## Appendix25: Survey and Interview Information Pack

My name is Blessing Mafimisebi, I am sending this information sheet to you with the purpose of outlining my study procedures, inform you of your rights as participants and the data being collected from you in this study.

I wish to inform you that I am a PhD candidate, studying at Anglia Ruskin University, Chelmsford, Essex, United Kingdom, department of Engineering & the Built Environment in the Faculty of Science & Technology.

My supervisor contact is telephone lines at +44 (0)1245683907 or 0845193907.

*Kindly read the content below carefully*

### Purpose of the Study:

The purpose of the study is to develop an Assessment and Benchmarking Framework for reducing building energy use that enable owners and facilities managers identify appropriate operational, technical and behavioural solutions for existing building stocks.

### Procedures for study:

After you reading the information provided about the study above, and upon your acceptance to participate based on the consent form, we can proceed with the interview as scheduled. The interview discussions will be focused on contextual issues raised in extant literatures in formulating the new framework model; and key findings from the surveys and the analysis of operational data mined from case buildings. Also, the interview will be recorded (via audio recorder), and it is suggested that you leave 30 minutes for the interview period.

### Voluntary participation

The participation of all respondents as well as yours is voluntary. You have the right to decline to answer any question and free to stop the investigation at any time. Also, you are assured that there is no penalty attached to your refusal to answer any question and stopping the investigation. Moreover, in case you leave the study, any data collected from you and your property will be deleted.

### Right to Ask Questions:

You are always welcome in making any enquiry on this research by contacting Blessing Mafimisebi at [blessing.mafimisebi@pgr.anglia.ac.uk](mailto:blessing.mafimisebi@pgr.anglia.ac.uk) or on +447494338293.

### Data usage:

The collected will be used for a PhD study on 'A Framework Model for Reducing Energy Consumption in Existing Buildings: A Case for Owners and Facilities Managers'. In addition, it might likely be used for contributions to academic publications.

### Confidentiality & Anonymity:

This is to inform you that your participation in this research data collection is confidential. You will also have the option of opting out of anonymity where you don't mind having your name and company revealed in this study. If you choose to remain anonymous in this study, your name will be coded and your original identification will be stored safely for the duration of this research. All audio recordings will be stored safely during the duration of this research and will

be destroyed after its completion. Finally, no information will be passed to anybody connected to you; and your participation is subject to you being 18years and above.

#### *Consent Form*

My name is Blessing Mafimisebi, I am sending this consent form to you with the purpose of outlining my study procedures, inform you of your rights as participants and the data being collected from you in this study.

You might wish to confirm my status as a PhD researcher at studying at Anglia Ruskin University, Chelmsford, Essex, United Kingdom in the Faculty of Science & Technology, by contacting the Head of the department of Engineering & the Built Environment on [+44 \(0\)1245683907](tel:+441245683907) or [0845193907](tel:0845193907).

Kindly, indicate your consent or decline by answering the following questions:

1. I happy to participate in this research
  - ☐ Yes
  - ☐ No
2. I am happy for the interview to be recorded via audio recorder
  - ☐ Yes
  - ☐ No
3. The anonymised records may be used to show other researcher and / or to students in classrooms
  - ☐ Yes
  - ☐ No
4. I will like to opt out of anonymity and my identity used
  - ☐ Yes
  - ☐ No

Please sign and retain a copy of this consent form for your records.

Signed (participant).....

Name.....

Date.....

Signature of Researcher.....

### 1. Building Energy Use and Climate

Studies have established relationships between BEU, global warming and climate change (CCH), hence, the perception of interviewAppendix26: Details of Participants' Interview- Interv-Surv4ees on this is obtained via the question:

***‘What do you understand by global warming, CCH and building CO<sub>2</sub> emissions?’***

The result indicates participants clearly understood these concepts and their relationships with BEU and BEP. Likewise, awareness on the correlations between building, generator use and GHGs emission is shown by the interviewees as expounded by one of them:

*“.... I am aware of climate change and global warming. It is about changes in weather and other atmospheric conditions. Shift in weather patterns are generally caused by global warming. Pollution could cause it. Generator’s use causes harmful unhealthy emissions that can cause climate change. Because the emissions are not healthy. Everybody is emitting these gases. .... buildings, factories are emitting GHGs” Case04.*

The respondents confirmed that the climate is a critical component that affects BEP as GHG emissions is traced to the use of generators and other sources of BEU. Also, as indicated by one participant, there is linkage between cooling and ventilation equipment used for comfort in buildings to CCH.

*“.....We use cooling system, also having ventilation. Now most buildings are being changed to adapt to new climate issues” Case02.*

The findings indicate the respondent expressed causality in the relationship between climate and buildings. Consequently, it could be perceived that BEU causes CO<sub>2</sub> emissions that lead to global warming and consequently contributes to CCH; whilst, CCH leads to increased use of HVAC equipment in buildings for maintaining comfort. Hence, another interviewee argued for building climate adaptation and mitigations by asserting that;

*“Buildings are currently being planned to reduce heat coming out from them. The concept of green building is currently gaining ground in Nigeria. In terms of energy usage, the power from PHCN is not sufficient and constant. Every building is being*

*powered by a generator, and these generators produce heat, emissions and noise” Case01.*

They viewed government policy on BEP as an instrument of change that can address the problem:

*“..... If the government formulates policy, Nigerians will implement. We need government policy as an instrument of change” Case02.*

## 2. Management policy

Management policies associated with BEU are amongst most highlighted issues by participants. Sustainable policy (SP), operational FM, and strategic energy management (SEM) are major problems reported by participants. For instance, most respondents agreed that the problems are associated with an estimated billing policy of energy suppliers in both countries. Nevertheless, this is perceived to be more severe in Nigeria because of sharp practices. The estimated billing method is reported as a critical barrier that affects strategic energy planning, operational FM and other sustainable management of case buildings.

### I. SEM

Particularly, findings revealed that strategic planning for BEU becomes difficult as electricity cost is sporadic and volatile electricity supply persist. Estimated billing method deployed in generating revenue by vendors, makes SEM even more impossible especially in Nigeria. Findings identified it as critical barrier, based on the answers to the questions put to the interviewees:

***‘Do you have problem with estimated bills and how do you monitor your energy use?’***

All participants agreed that there is a high prevalence of outrageous estimated bills; and that in Nigeria, the bills come in irrespective of high frequency of electricity blackout. A participants (Case01), described his company’s frustration and helplessness on such outrageous bill:

*“We have problem with it, we were paying averagely between ₦65,000- 90,000.00 Naira with metered bills. Suddenly, PHCN came and disconnect our power, and gave us estimated bills. The estimated bills started with ₦350,000.00 but now it has gone up to ₦1,200,000.00- 1,400,000.00. When we complained, they insisted that we must pay. We’ve being receiving estimated bills since the past four years, they refused to repair the meter” Case01.*



This view supports the assertion of participant Case03, who says:

*“We have issues with its use. 25 companies are currently using this building with just one analogue meter instead of pre-paid meters. We do receive outrageous estimated bills sometimes. We received ₦350, 000.0 instead of ₦125, 000.00 in one instance, but when we protested it was revised. We preferred grid electricity to generator despite this problem” Case03.*

Poor energy management in Nigeria was cited as the primary cause for the high incidence of estimated billing use. As participant cas04 put it:

*“It all bored down to inefficiency of energy management in Nigeria. Generally, power holding is there, at the end of the month they bring estimated bills of ₦6,500.00-8,500.00 of what you didn't consume or what you don't know about. The masses just pay and complain, because they are ignorant of what to do” Case04.*

Findings similarly indicate that the estimated billing method is also practiced in the UK, nevertheless the modus operandi differs from that of Nigeria. It is a standard practice based on standing agreement between users and vendors. In the UK, the customer must also provide information on meter readings to the vendors within a window. If there is no information, then the vendor can issue estimated bill, however, this should not be more than twice in a roll. Respondent's case07 explained it as thus:

*“..... For non-half, hourly electricity supplies... they are generally billed quarterly, though meters are read monthly, and they can be estimated. We do occasionally get estimated bills and we challenge them when we have queries. But in all cases, we try not to have more than two estimated bills in a roll. Gas is much easier based on monthly bills for all suppliers” case07.*

This assertion also agrees with the view of participant case06 as expressed thus:

*“Always, sometimes they don't use our rates, they provide us with estimated bills.... We will not pay more than two estimated bills in a roll. If we get third estimated bill in a roll, we query it, we have to call them say no this is our readings” Case06.*

As it was espoused earlier, the result confirmed that estimated bills could mar data analysis subject it to errors, leading to non-robust and unreliable forecasting, and serves as critical barrier to SEM.

*“..... If we receive too many estimated rates/ bills it mess all our energy forecasting, data analysis and preparation. Sometimes we have erroneous rates, such as real random rates that can result in high bills. In all our lease houses (domestic properties), for students’ accommodation, they provide us with unrealistic estimated bills that resulted in £5,000.00 bill instead of £2,000.00 bill” Case 06.*

Finally, corruption was also cited as the underlying component for the outrageous bills associated estimated billing method in Nigeria. Participant case05, also reported sharp practices and agreed to have problems with the method.

*“Yes, NEPA (PHCN) officials will bring outrageous bills such as ₦30,000.00. When you go to their office to protest, they will be soliciting to help you to bring it down to ₦10,000.00. Now, when I purchase a card, I spend between ₦2500 - 3000 per month, though in my office I don't have much equipment” case05.*

Sharp practice, however, was not shown as an underpinning factor for the UK phenomenon, but, irregularity and outrageous bills are also shown. This is deducted from;

*“..... In all our lease houses (domestic properties), for students’ accommodation, they supply us with unrealistic estimated bills that resulted in £5,000.00 bill instead of £200.00 bill” Case 06.*

This opinion concurs with another UK’s respondent Case07 view, who expressed disappointment with his organisation's electricity supplier’s attitude:

*“..... Nevertheless, with electricity, I think our energy companies simply want to view themselves as pumping electricity through wires and pipes, whether we use them or not, they still bill us for it. But we are asking more searching questions about our suppliers now” case07.*

## **II. FM**

The result reveals existence of problems associated with operational FM in Nigeria’s companies using case study buildings. The use of fuel-based generator is identified in the daily operation of these facilities. Also, these organisations lack routine repair and maintenance plan for generators, and often associated tasks are dedicated to non-technical staff and unskilled technicians. The interviewee’s answers to the interview question below also support this determination:

***‘Is maintenance of generators or BEU a management issue in the organisation?’***

*“Yes, I have generator, I can't depend on NEPA because at times, there will be no light for 24hrs and I use generator to run my business as an alternative” Case 04.*

The CEOs and all facilities managers agreed that they are involved in maintenance, hence is perceived as a management business. This is expressed in Case01 reply:

*“Yes, the team report to me, I report to the management” Case01.*

The deduction from their respective follow up answers (Case02 and Case05), shows they often dedicated it to staff.

*“Yes, the accountant who is in charge report to me directly Case02”. Whilst another said, “I dedicate it to a staff and engage technician”*

### *III. SP*

Study literature has shown the importance of SP in sustainable management of BEU and improvement of BEP. Findings revealed that the five UK's case building are managed with environmental management policy, and energy management plan as strategic documents. This is strategically driven by an environmental team. Whilst, some of the organisation within the Nigeria case buildings don't have such policies. However, they all promote the values and practices of sustainability with sound corporate ethos within these case buildings. They totally desire to be perceived as an environmental responsive company as indicated in respective responses to query below.

***‘Do you have a sustainability policy statement; and what is your business ethos?’***

*“Yes, we have written policy document with code of conduct” case05; “Our major core values are integrity, honesty and probity” Case05.*

*“..... To be known as a reputable company... Yes, I have, but only management staff have access to SP document” Case04.*

Participants Case04 and Case05 assertions that they have SP, might be true, but they don't seem to have strategic drivers to propel their daily operations within the SP document in achieving BEU reduction. Other interviewees agreed that their organisation doesn't have SP.

*“..... Fresh staff, we educate them about our energy policy, waste management issue, and water management issue. Though we don't have written sustainability policy, but we practice sustainability and energy management” Case02.*

*“A role model for environmental awareness. We're educating people..... On carbon emissions and climate change... We bought a brand-new concrete mixer instead of fairly used.... because of pollution” Case03.*

It was only Case01 that have quality management policy that is driven with an energy team.

*“Arup have good and sound corporate ethos.... company operations are governed by engineering ethical standards..... We don't have written SP statement, simply we have ISO quality management policy....” Case01.*

The operation of strategic drivers by case Bdlg101 might help in its better management amongst the Nigeria case buildings as initial OST assessment in the current study.

Whereas, the UK's participants strongly advanced the use of their organisation's SP and its strategic drivers for improving the EEP of its' estate buildings.

*“Yes, Anglia Ruskin University has an environmental policy which encompasses energy, water, waste, recycling..... There is strategy behind it that is driven by the environment team. It is a university wide decreed policy. There is also energy and carbon management plan that covers specific energy consumption and CO<sub>2</sub> emissions” Case06.*

Across all interviewees' opinion, there is a general accord that SP and strategic drivers in the form of structure and staffing in the organisation is a prerequisite for reducing BEU and improving BEP.

### 3. Operational Issues

Generally, the interviewees indicate that the Nigeria case buildings have more operational problems compared to the UK cases. Operational assessment based on perceived comfort, embedded technology, FM's roles and energy assessment metrics indicates relationships between these reflective indicators and BEP.

#### I. Comfort

Respondents' opinion on comfort perceptions of the buildings varied within and across case study buildings. Particularly, interviewees were asked this question:

***‘How would you rate this building comfort?’***

Most Nigeria, participants perceived their building to be comfortable. However, the argument of Case01, reveals that Bldg101 comfort is driven constantly with air cooling equipment with its heavy energy consumption demand.

*Case Bld101 is perceived as “... comfortable, the air conditioners are constantly on” Case01. Whilst, Case Bld104 is perceived “..... comfortable” Case02.*

Also,

*Participants Case04 perceived Bld103 as “the building itself is ok, the daylight is ok; and the general comfort, I will rate it 40%. Is a bit comfortable”*

This perception supports the view of participant Case05 on the same building, who complained of lack of ventilation:

*“There is ventilation, air comes in but insufficient, but when there is not light is very hot” case05.*

Thus, faulty design and wrong choice of construction materials were identified as major causes of discomfort in buildings Bldg104 and Bldg206. Finding also revealed that such design and construction decisions do affects BEP during its operations. Particularly, the interviewee (Case03) argued for important of daylight gain as emphasises that:

*“Comfort is fairly ok. The problem is electricity supply to the building.... building also has issue of non-entry of natural daylight into the offices” Case03 for Bld105.*

Finding also revealed that such design and construction decisions do affects BEP during its operations as indicated in participant case07 argument.

*“.... Marconi building is made up of light weight structure, it takes a long time to heat the building up and it doesn’t retain the heat. It is fitted with full electric heating system” Case07.*

The relevance of using technology to take over users’ behavioural control; and regulate comfort in buildings are emphasised by participant case06. She contended that:

*“Marconi has some issues. The difficulties we have is when you give control to the occupants over the heating and the cooling, you’re going to have some people hot and some cold.....So we ensure that occupants can only have their temperature adjusted by 1°C. Hence, we keep the comfort temperature control between 20-21°C...recommended...comfortable temperature” Case06.*

## **II. Technology,**

Findings based on a question below, indicate that all the Nigeria case buildings are rated poor compared to the UK cases in term of embedded technologies.

***‘What is the relevance of technologies in this building?’***

Most of the Nigeria interviewees said case buildings lack modern technologies. Case bldg103 is:

*“There is absolutely nothing like that; I rate the building zero, in terms of tech embedment” Case05. And “I would rate it 10%, there is no lift, no CCTV” Case04.*

Interviewees Case02 and Case03 similarly assert that case bldg104 and bldg105 are poorly rated:

*“There is no access control, and the Lift is not working. The faulty lift because of power outage..... building is poor in technological rating” Case03.*

*“The building is poorly rated in terms of technology installations. When I travel abroad, at the hotel you are issuing slot card for access in your room, and for control of energy use. Slot cards technology compliment human energy efficient habit” Case02.*

Whilst, it was only case bldg101 is seen as: *“Fair, it is not bad” Case01.*

The result indicates that technology compliment human energy efficient habits; and also faulty technology due to lack of repair can aid poor BEP.

The UK participants, both agreed that technology is very relevant in BEP and that they are useful for: energy saving; fight against behaviour control; data acquisition and storage; accurate billing; data analysis and forecasting; and for strategic energy planning.

*“.... If you really want to make big energy saving reduction..... invest in technologies. You need the technologies to.... fight for behaviour change and communication messages..... You need the technologies to be in place and to work.... and to keep*

*working. But things like monitoring energy data, the energy data we are getting is very invaluable to us. It is very important to us” Case06.*

*“...Take for instance, in Marconi, we have 30 sub meters; so, in theorem we are able to go down to fine level of details in tracking high energy usage in the building.... Relatively we can track down details where energy is being used. But, I discovered that all metering hardware and software is very fragile. It creates a huge amount of problems trying to maintain a usage database for these meters and networks. ...we are working hard to make the technology work for us. It is a constant battle to find technology that is robust enough, we are making progress” Case07.*

Interviewee Case07 however, cautioned on the usage of technologies in buildings in achieving EE. He emphasised the need for skill, and competent staff in choice of embedded technologies.

*“I think it is a double edge sword with technology, it can help you, but it can also undermine you greatly in terms of EE. Marconi building, it was handed over to us in 2008 with some complicated management system and integrated software...We had our sustainable engineer, who reconfigured all the software in that building because it was never configured correctly from the start. With technology like that if we don't have a competent skill staff .... It can work against us likewise with meters” Case07.*

### *III. FM department/ roles,*

The result indicates that all organisations using the Nigeria case buildings except bldg101, don't have dedicated FM department. Although, FM functions are taken up by top management staff and executive themselves. Responses to the question below confirms that organisations dedicate FM roles to non-expert staff who lack the competency in operational FM.

***‘Do you have dedicated staff assigned to FM and energy use?’***

*“Yes, we have. The accountant is in charge” Case02.*

*“We don't have dedicated PM staff managing energy use and cost” Case05*

*“We tackle it ourselves, I have staff that can do this” Case04*

The findings also revealed FM roles in the organisation as contained in the argument of case01. According to him, it involves: ensuring of constant power supply, monitoring building energy supply and use, and performing constant routine and planned maintenance (generator).

*“Yes, we've facilities in place and we've people in charge of these facilities. We've the power supply team, they ensure that there is a constant supply of electricity. They*



*monitor energy supply and usage within the building, and ensure constant routine and planned maintenance of generators” Case01.*

#### *IV. Assessment metrics*

Findings in both countries, indicate that choice of metrics is often based on peculiar needs. Energy PMs, such as BEUI (kWh/m<sup>2</sup>), BECI (£/m<sup>2</sup>), and prepaid metered billing based on kWh/month are the most preferred. Based on interviewees responses to the question below,

#### ***‘How do you assess and monitor your BEU?’***

Study results on energy assessment and monitoring PMs is encapsulated in participant Case06 response:

*“We look at varieties of different things. When ... trying to communication messages to staff and students, some time we might say per m<sup>2</sup> ...quantity of energy... Sometime convert it into cost..... Sometime per kWh. We use cost as people can easily relate with it. The choice of metric is actually based on needs at a particular time” Case06.*

In Nigeria, the BECI (£/m<sup>2</sup>), BEUI (kWh/m<sup>2</sup>), BEU/month (kWh/month), and the prepaid metered billing are the most commonly practiced. Interviewees’ Case3 and Case2 assertions support the use EUI (kWh/m<sup>2</sup>), and the kWh/month.

*“I prefer metric based on the cost of energy per m<sup>2</sup>” Case03.*

*“I prefer kWh/month as standard metric... We prefer litre/day as a tool for better management of energy use” Case02.*

Other interviewees, case4 and Case05 argued for prepaid metered based on kWh/month as monitoring metrics.

*“We use the metered bill with prepaid card” Case04.*

*“I prefer the cost per month that by how much I recharge. When I buy the card... It gives an average of 100-120kw.... I prefer the cost as monitoring metric....” Case05.*

Finally, participants in both countries agreed that BEU, BEUI, BEC and BECI are the most acceptable forms of PMs/KPIs.

### 3. Sustainable Building Management- Built Asset Management

Study results (based on question below), identified energy monitoring and targeting, adoption of green construction, government regulatory policy on BEE, adoption of renewable, as the best methods of achieving BEP.

***In what way, can BEU be managed more efficiently?***

The UK's respondent case07 made a case for energy monitoring and targeting via the use of robust technologies as an efficient method of managing BEU. He explicitly argued for half-hourly energy use data monitoring and retrieval as a baseline for effective energy management. He explains why,

*“The key thing.... is monitoring and targeting. We need to get accurate half-hourly data for the supplies going into our buildings.... This is one of the baseline requirements for effective and efficient energy management practices. Once you have that (half-hourly retrieved data), then you can do all the basics of energy management: we can identify anomalies, identify potential opportunity for savings; and you can also start moving on to the more sophisticated phases of energy management: mining sort of big data store”*  
Case07.

The Nigeria's interviewees' (Case02 and Case03) views represent more of the prevailing problems in existing in the country. Whereas, interviewee Case02 highlighted renewable uptake and government policy intervention as the solutions for efficient building energy management. He reasoned,

*“We must embrace greener buildings, Nigeria has enough solar energy. Government must put a policy in place for building energy efficiency. The government can bring in solar panels into the country and sell out at cheaper rate to the citizen. Inverter and solar PV panel are the solutions”* Case02.

Interviewee Case03 on his part believes the critical solution is constant and adequate grid electricity supply to buildings. He explicitly drew a positive correlation between grid electricity supplies to buildings and: BEE, energy cost reduction, increased productivity and comfort; by stating that,

*“Constant and adequate electricity supply from PHCN, means more efficient buildings, more productive and comfortable buildings. No noise pollution, No environmental pollution. Grid electricity is cheaper and more cost effective than generator based*

*electricity..... As an average Nigeria building owner, you generate your own electricity and water. You buy your own incoming power cable, electricity poles, meter and even transformer, is a lot of money” Case03.*

#### 4. Barriers and Drivers

Study findings have identified barriers and drivers to operational FM, SMB energy use, and building energy supply as critical factors that affects BEP.

##### I. Facilities Management

Interviewees acknowledged that there are challenges facing FMs based on the question below. However, it was found that these challenges are quite different in the UK from that of Nigeria, they are peculiar based on location.

***What are the challenges facing facilities managers?***

Particularly, interviewee Case06 argued that the matter of funding for investment in technologies and renewables, and occupant inefficient behaviour are most critical barriers to FM roles in the UK. She explains:

*“.... As we need money to fund technologies, so money is a barrier. For example, if you want to put in place CHP plant, solar PV, LED lighting, you must go and find money to do these. Also .... Occupants’ behaviour is another barrier. People will make energy savings in their home, but when they come to work, they are not bothered or really concerned..... It’s all about..... why should I bother about energy conversation” Case06.*

Interviewees Case01 and Case02 both concurred that inadequate and irregular national grid electricity supply is a critical barrier to FM. Their opinions also collaborate earlier assertion of Case03, which they all argued, led to the use of generators in buildings in Nigeria. As they put it;

*“The basic challenge is the inability to get the power supply from the national grid because is the cheaper option. Most people buy diesel to power their generators” Case01.*

*“Nigeria has power problem; the national power grid is not forth coming. Hence, we run on generator” Case02.*

##### II. SMB Energy Use

Findings suggest that participants stress more on the barriers to SMB energy use than drivers.

***What are the barriers & drivers to sustainable management of BEU?***

Particularly, arguments of Case01 and Case03 highlighted inadequate supply, corruption, and short term planning as barriers in Nigeria. Interviewee Case01 cited fuel scarcity additionally as barrier, as he explains that:

*“The barriers.... Are short supply, corruption.... Short term planning, and fuel scarcity” Case01.*

Case03 advances it further by citing occupant attitudes, owners’ business management style as additional barriers. Besides, he cited building refurbishment and lift’s maintenance /repair as possible drivers by stating that;

*“The barriers are short supply, corruption, short term planning. Barrier is the attitude of occupants. The approach of the landlord, how he manages his business is a barrier. Drivers, he can give the building facelift, repair the lift that is not working” Case03.*

***III. Building energy supply,***

Participants identified frequent power outage as causes of lack of electricity supply to buildings; and high incidence of generator use in building in Nigeria.

***What can be done to improve energy supply to this building?***

*“There is always blackout and we use our generators. Electricity outage is a big problem in Nigeria, every successful government tries to solve. The government should investigate (dissect) power issues and the company to solve it. Some of the problem are Corruption, inefficiency, and lack of dedicated staff. The mind-set of staffer of electricity production, supply companies should be corrected..... Maybe we should look at the solar energy source. .... Inverter comes handy, useful and it is noiseless” Case05.*

*“Power holding can do something like a research on how to improve their services. Research will reveal a lot about what is happening and possible solutions” Case04.*

**5. Business Practices**

Findings revealed there are peculiar problems associated with energy supply chain in Nigeria that are not in existence in the UK.

## *I. Energy supply chain*

***What are the problems associated with energy supply chain (grid electricity to diesel supplies)?***

Interviewee Case04 expounded that corruption, poor infrastructure, lack of maintenance, inefficiency, fuel scarcity and poor management are responsible for poor state of energy supply and network distribution in Nigeria. This view concurs with earlier findings based on other interviewee's views, as she put it;

*“Supply chain is very poor and I will rate it at 20%, it is corruption. No infrastructure, no good maintenance, inefficient manpower and lack of adequate management. Getting the fuel into the generator is another problem. Scarcity is one problems. They import fuel every day and when you get to the filling station no fuel” Case04.*

This position is corroborated by the argument of case02, who illustrated vividly with a wide range of these problems. He asserts;

*“There is vandalization and stealing of cables. Nigeria is still transporting petroleum products with tankers to the west, north, east and southern parts of the country, the logistic is poor. Abroad they use the train, and underground piping networks. How many tankers can satisfy 174million people? They're too few depots for distribution and supplies” Case02.*

Case06 confirms that such problems do not occur in the UK. The UK's energy supply practice allows for a broker as an intermediary, which is now in existence in Nigeria. Likewise, energy companies are often efficient to supply by standing vendor contract agreements. She asserts;

*“I don't necessarily see any problem. We use a broker to get our vendor, we never have any problem getting electricity to the buildings. Any time our contract expires our broker just inform us and ask for renewal with the electricity companies. Also, a power cut will be extremely rare extremely rare’Case06.*

## *II. Corruption*

Findings linked sharp practice to business practices associated with the Nigeria energy supply chain. All the interviewees believe corruption is a critical factor that should be eradicated in the system.

***What is opinion about business as usual in the energy supply chain?***

Case04 expound on the consequences of corruption in the energy supply chain in a nation's development; and concluded that it is Nigeria most cancerous problem, as she argued that;

*“Energy is a very important sector in every nation, energy drives a nation. Inability to provide sufficient energy in a nation, can ruin that nation, it can lead to under development; and corruption is the greatest problem in Nigeria. If we can decide to work efficiently, the energy problem in Nigeria will be solved. .... Even businesses are relocating to Ghana, neighbouring nation because of stable power” Case04.*

Findings also linked corruption to an organised system run by a certain clique based on participants' views. Particularly, Case02 x-rayed the underpinning causes of corruption, and agreed with case04 that corruption is the most critical problem.

*“It is the system, the cabal, the clique. For instance, PHCN who is the producer of electricity uses generators to collect revenue, it is an irony.... Several problems are associated with energy in Nigeria, for it to be solved, corruption especially, must be stamped out” Case02.*

This assertion is supported by the view of Case03, as he linked importation of generators to this clique. He claims;

*“Most PHCN's directors are the ones involved in the importation of generators before privatisation. They are involved in frustrating power projects & programmes all over the country, ensuring that they are not successful. They are profiting from the crises, if the privatisation can work very well, it can reduce this barrier” Case03.*

## 6. Regulatory energy policy,

Finding reveals that the current structure and activities of the Nigeria oil & gas sector have a negative impact on the BEU and its EEP. Particularly, participants assert that the inefficiency in the sector is connected mainly with corruption.

### I. Oil & gas politics

#### **What is your take on Nigeria oil & gas politics and BEU?**

The result indicates that despite the institutional reform like the power reform via the privatisation of power sector, energy crisis persists. The current electricity production is lower than 4,000MW, which, per the opinion of interviewee Case02 calls for several questions.

*“There is a powerful reform that is not working because there is no political will. When this government came on board, we have more 4,000MW, today we have less than 4,000MW. They sold the power distribution companies to themselves. In the petroleum sector, why is it that our refineries are not working? Why the government can’t set up micro refineries in the six geopolitical zones of the country? Why we do sell our crude oil and go back to import refined products outside Nigeria? The current government doesn’t have the political will to effect change” Case02.*

The argument of Case04 however, seems to expose the underpinning reasons for the current crisis and linkage with energy use in building. She expounds on likelihood of conspiracy and issue of round tripping of Nigeria crude oil and refined petroleum products. She explained;

*“Nigeria oil & gas sector should be restructured now, because most businesses in Nigeria have crumbled. They have turn the common man into deeper energy poverty. Some people cannot afford energy in Nigeria. They export crude oil and import fuel into the depots, getting the fuel out of the depots to the filling stations is a problem, the tankers can queue for 3-4days without getting anything. They create artificial scarcity. Since, it will be more expensive and they can make more money for themselves. We use fuel daily in this office, getting to us the end-user is another problem” Case04.*

The restructuring of oil & gas and the power sector is likewise suggested by most of the respondents.

## *II. Corruption*

Findings also identified corruption has been associated with policy, regulation, hence impact BEP. Participants are asked to express their opinion on the question below.

***What is your take on corruption as barrier to regulatory policy effectiveness in terms of BEU?***

The result indicates linked corruption to poor policy implementation; non-execution of institutional framework; and sabotage of government reform programmes. Most interviewees believe there is a conspiracy between stakeholders and policy regulators in the industry. Particularly, case01 associated corruption to nepotism, where the wrong people are responsible for policy implementation, as he put it;



*“There is corruption everywhere... Corruption start when you put the wrong people in a position that they don’t fit into the policy. The problem also is when people making policy they don’t understand why they are making such policy.” Case01*

The non-performance of institutional framework is also cited by Case03 as the principal cause for sharp practices by an Electricity Company’s staffer. He stressed;

*“...We don’t have policy and regulatory agency also .... One funny man can appear at your gate, disconnect your light, and if you bribe him, he connects it back” Case03.*

Corruption is also tied to political cabal who profit from the energy crises. Case02 assertion, which connected earlier thinking of Case04. Case02 opined that these cabals use the weapon of sabotage to frustrate government programmes. He argued, the cartel oversees importation of fuel and generators as thus:

*“The close factor like a cartel or political cabal. Also, people importing generators are sabotaging the energy supply and reform programmes. Nigeria holds the highest import of generator worldwide. In one premises, you can infer more than 3-4 generators working at the same time. Generators importers .... Fuel importers also making huge profit. So, they might sabotage as well. There is conspiracy by importers of generators and fuel, and government officers paying subsidies on imported fuel” Case02*

### *III. Energy policy*

Study findings revealed that unlike the UK, there is no building energy code in Nigeria, and even the existing energy policy is not known to most of the interviewees.

***Is there a regulatory energy policy and building energy code in this country?***

Case01 stressed that regulatory policy is not in existence in Nigeria as explained:

*“I’m not aware of any, there is none in place. Policy formulation and implementation is an emerging thing in Nigeria” Case01.*

Case04 is aware of the Nigeria energy policy, but expressed concerns over skill and poor implementation. She emphasised that code guiding emissions from buildings is needful:

*“I’m aware of energy policy in Nigeria. But just that the policies are not working, they write out policies, and they don’t implement it. .... There is no code guiding emissions*

*from building in Nigeria. Everybody is emitting, there is no code guiding consumption” case04.*

Interviewee case07 explained that their organisation does not encounter regulatory compliance problem and they often surpass it. This could have traced to the effects of regulation and compliance in the UK, which Nigeria can leverage on. He stresses;

*“..... We don't struggle at all to meet the building regulations or planning conditions. If there is any we go beyond the requirements as we use breeam in our new buildings. We don't struggle with compliance” Case07.*

## 7. Low-Zero Carbon options

### I. Renewables,

Findings indicate that renewable energy interventions such as solar PV panels, solar thermal, inverter, low energy saving bulbs are advanced by participants as the best method of improving BEP. However, the only exception is the use CHP as intervention in the UK.

***What is your take on alternative energy sources like solar PV panels, solar thermal?***

All Nigeria, participants shared the same opinion with Case02 who argued that;

*“.. To reduce costs, we must embrace greener buildings, Nigeria has enough solar energy. Government must put a policy in place for building energy efficiency. The government can bring in solar panels into the country and sell out at cheaper rate to the citizen. Inverter and solar PV panel are the solutions” Case02.*

The two UK participants upheld similar view, as Case07 explained the University strategy of integrating such intervention on a phase basis:

*“.... We always have some research system daily. Essentially, every new building we have PV on them. In Chelmsford, we got about 10-15kWa on the Medical Building. We also commissioned the energy centre with CHP. The gas-fired CHP is lower carbon CHP” Case07.*